SPOLIA ZEYLANICA

VOL. XIX.

SEPTEMBER, 1934—FEBRUARY, 1936

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ERRATA

CEYLON JOURNAL OF SCIENCE (SECTION B) VOL. XIX

p. 167, line 38, *for* " Plate XXI, figs. 1 and 2) " *read* " (Plate XX🌢, figs. 1, 2, and 3) ".

p. 168, line 23, *delete* " (Plate XI, fig 3) "

Plate XXI, Fig. 1, *for* " Kantalai " *read* " Gallodai "

Fig. 2, *for* " Fine-grained dolerite Kalkudah " *read* " Dolerite dyke Kantalai "

Fig. 3, *for* " Flow-structure round olivine in marginal portion of dyke, Aluketiya (× 30) " *read* " Dolerite dyke, China Bay (× 10) "

New and Rare Hexacentrinae (Insecta, Orthoptera) from Ceylon

BY

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(With Three Plates and Three Text Figures)

The greater part of the material on which this paper is based has been collected by Mr. W. W. A. Phillips to whom the thanks of the Department, and my personal thanks, are due for his keenness in obtaining specimens and generosity in presenting them, at no small cost to himself, to the Colombo Museum.

Phisis kelletti Henry

Plate III, Figs. 6 and 11

Phisis kelletti Henry, 1932. *Ceylon J. Sci.* (B) Vol. XVI, p. 243, Plate XLVII.

Four specimens [1] of this species (two males and two females) have been sent to the Colombo Museum by Mr. Phillips, and this material enables me to supplement the original description, which was drawn up from a single adult male and a female larva, and to add a description of the adult female. Unfortunately, one of the males is teneral and has shrivelled badly in the process of drying, and one of the females has a deformed ovipositor.

♂. This agrees closely in the main with the description of the type (now in the British Museum); however, in the genitalia, the medial margin of the anal tergite is not produced into a dorsally-directed lip

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[1] After this paper was sent to press, Mr Phillips forwarded the following additional specimens collected in February and March, 1934 : three from Mousakanda (c. 2,400 feet), and two from Elahera, in the low-country, about 16 miles N.N.E from Mousakanda. They were all collected as young larvae, but one of the Mousakanda specimens (♀) and the two Elahera specimens (♂, ♀) have been reared to maturity and are still alive in my laboratory. The remaining two Mousakanda specimens (♂, ♀, juv.) are developing satisfactorily. They are fed on *Drosophila*. The larvae of the Mousakanda specimens have a well-marked, brick-red, dorsal, median stripe extending from the front of the pronotum to the anal segment: this stripe was much paler in the Elahera larvae, which led to a surmise that they would prove to be of a distinct species; but the adults show no difference from the Mousakanda specimens.

as shown in my figures (*loc. cit.*, Figs. 3 and 5), and the cerci show, in addition to the ' small, inwardly-directed tubercle ' at the tip, a strong ridge proximal to the tubercle; and the two form the margins of a deep, narrow gutter on the postero-dorsal part of the cercus. The rami of the titillator are even longer and more strongly divergent than in the type.

In coloration the new specimens agree with the description, so far as it goes, but there is a diffuse yellow band along the dorsum of the pronotum and continued along the inner margins of the tegmina. In the latter, most of the smaller venules are crimson brown, contrasting with the main veins and their branches, which are green. This feature was observed in the type but, being regarded as possibly due to post-mortem discoloration, was omitted from the description; it is now found, however, to be present in the living insect. The wings are pale greenish hyaline.

The armature of the hind tibiae in this insect agrees in the main with that described below in *Decolya* (p. 5 and Text-fig. 1) but the outer, dorsal, sub-apical spur is absent and the two ventral apical spurs are proportionally smaller.

♀. This agrees with the ♂ in all ambisexual characters and in size. The genitalia are fully figured in Plate III, Figs. 6 and 11 so that there is no need for me to describe them in words, but it may be mentioned that the sub-genital lamina is transverse, strongly gibbose, and deeply sulcate medially. The ovipositor is very minutely serrated towards the tip dorsally and much more coarsely serrated ventrally. Its ventral valves show no trace of the small tapering processes on their proximal portion which are present in some species of *Decolya* (see below, p. 6).

Measurements

	♂ mm.	♀ mm.	♀ mm.
Length of body (ovipositor in females not included)	14.0	18.0	18.0
Width of head, including eyes ...	2.9	3.0	3.0
Length of pronotum ...	3.8	3.75	3.9
Width of pronotum ...	3.3	3.25	3.15
Length of tegmen ...	21.7	24.5	25.0
Length of fore femur ...	6.5	6.7	6.6
Length of fore tibia ...	7.5	8.0	7.8
Length of hind femur ...	11.4	12.2	11.9
Length of hind tibia ...	12.5	14.0	13.9
Length of ovipositor (base ventrally to tip)...	—	(deformed)	13.8
Width of ovipositor, dorso-ventral ...	—	,,	1.4

It will be noted that the measurements of the Mousakanda ♂ are greater in some particulars (notably in the pronotal measurements) than those of the type, and sub-specific distinction may be indicated but further material must be awaited before any pronouncement can be made on this point.

Remarks. The four specimens were captured by Mr. Phillips by beating the branches of jungle trees over a butterfly net, at Mousakanda Estate, Gammaduwa, at an elevation of about 2,800 feet, on the following dates: 6-iv-33; 8 to 13-v-33; and 29-vi-33. Two of them were captured as larvae and reared to maturity in my laboratory. Their general habits were the same as those of *Decolya* (see below) and they fed readily at night on small diptera such as *Drosophila* and *Musca*, which were captured by a clap-net action of the fore- and mid-legs. They appear to be hardier than any of the species of *Decolya* known to me, as I have never succeeded in rearing the latter to maturity from any larval stage.

A female specimen will be presented to the British Museum (Natural History).

Genus **Decolya** Bolivar

Four new species of this genus are described below and remarks are offered on *D. roseopicta* Uvarov (1927) and on *D. splendens* Henry (1932). Before dealing with individual species, however, I wish to draw attention to certain general features of this genus as found in Ceylon. Many of my remarks will doubtless be found to apply equally to allied Hexacentrinae such as *Phisis*, *Estrinia* and *Hexacentrus*.

Habits. All the Decolyas known to me are strictly nocturnal; they spend the day clinging closely adpressed to the underside of leaves with the fore and hind legs extended fore-and-aft and the mid-legs with their femora laid alongside the hind femora and their tibiae extended more or less laterally; the antennae are carried extended in front of the head. In this position the insects are practically invisible, as their delicate, translucent-green coloration harmonizes perfectly with the green light transmitted through the leaf; in spite of this, however, Mr. Phillips informs me that he has observed the Ceylon Warbler, *Elaphrornis palliseri*, feeding upon them. All the

specimens have been captured in damp, shady jungle and they evince great intolerance of dry conditions or of too strong a light. Living specimens examined under magnification are always seen to be studded with minute droplets of moisture—produced, most probably, by secretion from glands in the cuticle. Specimens that I have kept in captivity eagerly drank the drops of water with which the foliage in their cage was sprinkled every evening.

The eyes, during sleep, are pale yellow with a dorsal spot of orange or purplish-red (according to the species), but when the insect is fully awake, and especially at night, they change to a deep red or purplish shade throughout; the mechanism whereby this change is effected has not been studied but it is doubtless similar to that which is known to occur in the eyes of other nocturnal insects.

Decolyas are voraciously carnivorous and my captive specimens were fed on small diptera such as *Drosophila* sp. and *Musca* sp. They were observed to capture their prey by leaping upon it and dexterously grasping it with the strongly spurred fore- and mid-legs. They are so translucent that the progress of the food, as a dark mass, may be watched as it traverses the alimentary system. They become very active after dark, running rapidly and taking long leaps. Unfortunately, observation of their habits has been hindered through their intolerance of light which makes them assume the resting position soon after they are illuminated. For this reason I have not been able to watch any of their more interesting habits, such as mating or egg-laying, and stridulation has not been observed, although, judging from the highly developed stridulatory apparatus in the male tegmina, it probably takes place.

Structure. With the exception of the genitalia this is very much alike in all the Ceylonese Decolyas, and were it not for the above-mentioned exception, specific distinctions would be exceedingly difficult to describe on paper, although fairly obvious to the eye. Fortunately however, the genitalia, especially of the males, offer very good specific characters which prove to be quite constant in the series of specimens of each species examined by me. Other apparently constant characters are afforded by the size and shape of the tegmina.

The maxillary and labial palps in *Decolya* are very long. Their terminal segments in life are cylindrical and swollen—turgid with fluid; but in dried specimens they collapse and become deeply concave ventrally.

The number of spurs [1] on the fore and mid-legs is constant for all the species known to me and is as follows: fore femur—4 pre-axial and 5 post-axial; fore tibia—7 pre-axial and 7 post-axial (not counting a pair of minute apical ones); mid femur—4 pre-axial; there are no post-axial spurs on this segment but there are 2 or 3 spines on the proximo-ventral portion, in series with a similar spine on the mid trochanter; mid tibia—6 pre-axial and 5 post-axial (not counting the minute apical ones) and, in addition, 2 dorsal, which are situated, one between the first and second pre-axial spurs and the other just before the distal extremity of the tibia. All the knee-lobes are spinous. The hind femora are armed, on the outer ventral aspect only, with 10 to 14 sharp, recumbent spines.
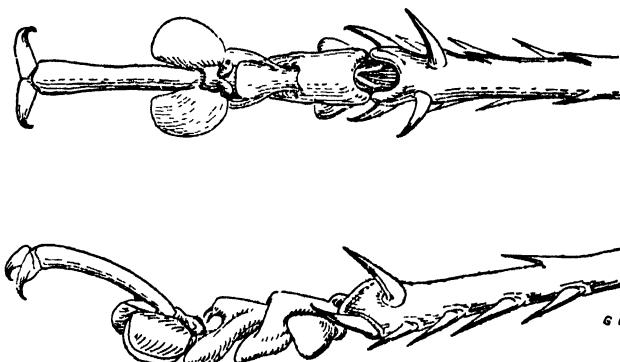

Fig. 1. Distal portion of right hind leg of *Decolya roseopicta* Uvarov, × 20

a dorsal *b* lateral

The hind-tibiae bear two series of sharp, recumbent spines dorsally and two series of small, sharp spurs ventrally; the dorsal spines are fairly evenly distributed almost throughout the length of the tibia but the ventral spurs only commence at about the proximal quarter of the segment and are sparse until about the distal third. The hind-tibiae bear a distal crown of 4 strong spurs, of which the dorsal pair are proximal to the ventral. (Text-fig. 1.)

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[1] The armature of the fore and mid femora and tibiae in this genus, and also in other Hexacentrinae, in Gryllacrinae, and probably in some other sub-families of carnivorous Tettigoniidae consists, for the most part, not of spines, as frequently described, but of spurs—*i.e.*, articulated structures. These spurs in *Decolya* and *Phisis* are normally set at a distal angle of approximately 70 to 90 degrees with the axis of the portion of the limb to which they are attached. From this position they can be mechanically depressed distally until they meet the parent segment, but proximally they are immovable. In life, after being depressed and released again, they automatically spring back to their normal position; I have seen no evidence that they can be actuated by muscular action.

The inner (post-axial) surface of the mid trochanter and femur in the above-mentioned two genera is armed with a varying number of true spines (unarticulated structures).

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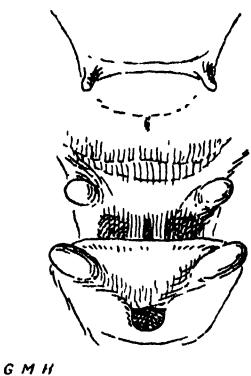
Fig. 2. Sternites of *Decolya roseopicta* Uvarov, × 15

(*N.B.*—The prosternal processes are strongly foreshortened.)

The prosternum is armed with two long, cylindrical, blunt-pointed processes and the meso- and meta-sterna bear a rounded knob on each of their antero-lateral corners. (Text-fig 2.)

As already remarked, the genitalia offer the best characters for specific discrimination. In the males (Text-fig. 3), the following structures may be noted: (*a*) shape of the anal tergite; (*b*) supra-anal plate with its two articulated appendages, (*c*) cerci; (*d*) titillator; (*e*) sub-genital lamina. It is to be noted that all the species possess a pair of long, tapering, fleshy processes, of a translucent white colour, which are normally coiled up and almost fill the genital cavity, but may be drawn out far beyond the cerci. In life these are capable of coiling and retractile movements. They shrivel to a large extent in dried specimens and their function is not understood although it seems probable that they are the intromittent organs These processes, in the retracted condition, are shown in Plate I, Fig. 5 and Plate II, Fig. 5 They are omitted from the other figures showing genitalia.

In the females, the characters which have proved most useful for distinguishing the species are the following: length and shape of the ovipositor; presence or absence of a pair of small, membranous, tapering processes [1] situated on the ventral valves of the ovipositor near the base; shape and sculpture of the eighth tergite in profile; shape of the ninth anal tergite; shape of the sub-genital lamina.

Coloration. All the species are pale, translucent green in life, with rather indefinite spots of deeper green arranged differently according to the species. The following general features may be noted. There

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[1] In dried specimens these look like small spines but in fresh ones they are quite soft and flexible.
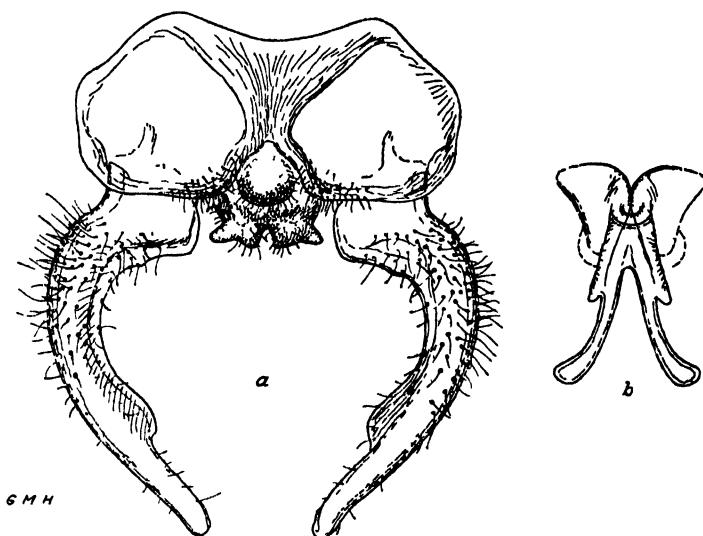
Fig. 3. ♂ genitalia of *Decolya roseopicta* Uvarov, × 20

a Anal tergite, supra anal plate with its appendages, and cerci *b* Titillator.
(*N B*—These figures were drawn from cleared preparations)

is a strong but variable tendency for the development of spots and small marks of dull crimson on the margins of the pronotum, on the tegmina, and margins of the abdominal tergites and in other places. In several species there is a tendency for more or less of the elytral speculum in the males to be black or smoky.

Decolya roseopicta Uvarov

Plate III, Figs. 1, 7, and 8; see also Text-figs. 1, 2, and 3 above

Decolya roseopicta Uvarov, 1927. *Ceylon J. Sci.* (B) XIV, p. 92, Plate XII, Fig. 1
Henry, 1932. *Ceylon J. Sci.* (B) XVI, Plate XLVIII, Fig. 5

Through the kindness of Mr. Phillips, the Colombo Museum now possesses a series of 18 males (in addition to the paratype male mentioned in the original description) and 17 females, preserved dry, and several adults and numerous larvae, of both sexes, preserved in spirits. This material enables me to offer the following remarks, and to describe the female, which was unknown when Uvarov described the species.

♂. The colour of the male in life is a delicate green with rather indefinite spots and bands of a richer green. The following dark crimson-brown marks are present to a greater or less extent; two broken, rather sinuous, lines on the dorsum of the pronotum, approaching each other in the middle; the posterior part of the lateral margins of the pronotum; the outer half of the file-bearing, transverse vein on the left tegmen; most of the vein which surrounds the speculum, and a band from the inner, posterior angle of the latter to the postero-internal margin of the tegmen; the outer side of the fore-coxal spine; short, transverse lines on the dorso-lateral margins of the abdominal tergites. The mid-femoral and tibial spurs are more or less pink. (*N.B.*—These markings are not very conspicuous and are almost absent in some specimens.) The dorsal portion of the left tegmen is yellowish and the speculum is dark smoky brown in some, more or less hyaline in others.

♀. Resembles the male in all ambisexual characters and in colour, but her crimson-brown markings tend to be paler. The tegmina are green, indefinitely streaked with pink and with their postero-internal margin lined with that colour. They are broadly oval, slightly obliquely truncate apically, in length about two-thirds that of the pronotum.

The eighth tergite has its antero-ventral portion strongly gibbose and posterior to this gibbosity there is a flange-like lobe projecting obliquely outwards, separated from the gibbosity by a deep, vertical furrow. The ninth tergite is broadly and somewhat squarely emarginate medially, its lateral portions somewhat gibbose. The ovipositor is shaped as in Plate III, Fig. 1. Its ventral valves bear, at the base, a pair of small, tapering fleshy processes (see Plate III, Figs. 1 and 7). It is practically smooth on the dorsal margin, minutely serrated for a short distance on the ventral.

Measurements

		♂. mm.	♀. mm.
Length	...	12.2 to 12.7	20.0 to 22.0
Width of head, including eyes	...	2.5 to 2 7	2.5 to 2.7
Length of pronotum	...	3.0 to 3.2	3.1 to 3.4
Breadth of pronotum	...	2.8 to 2.95	2.9 to 3.0
Length of tegmen	...	3.4 to 3.75	2.0 to 2.5
Length of fore femur	...	5.7 to 6.0	6.0 to 6.2
Length of fore tibia	...	6.3 to 6.7	6.9 to 7.0
Length of hind femur	...	9.7 to 10.1	10.6 to 11.4
Length of hind tibia	...	11.0 to 12.0	12.0 to 12.75
Length of ovipositor (base ventrally to tip)	—		10.0 to 10.2
Width of ovipositor, dorso-ventral	—		1.2

Remarks. This species is the commonest of the genus at Mousakanda and Mr. Phillips has sent in specimens in every month of the year except January. They were all taken in damp jungle, at an elevation of about 3,800 feet, by beating the branches of shrubs over a butterfly net. In habits, so far as observed in captivity, this species does not differ from the other Ceylonese Decolyas.

The type locality, Woodside Estate, Urugalla, is situated at the southern end of the mountain massif of which Mousakanda is on a northern spur, and its climate and elevation are very similar, so that it is not remarkable that this species has turned up at the latter place.

A series of specimens will be presented to the British Museum (Natural History), which at present possesses the type ♂ only.

Decolya splendens Henry

Decolya splendens Henry, 1932. *Ceylon J. Sci.* (B) Vol XVI, p. 247, Plate XLIX, Figs. 1, 4, 5.

It is of interest to record that additional material of this species, consisting of 3 adult males and a male larva in the penultimate instar, has come to hand, all captured at the type locality (Labuguma, Ceylon). They agree closely with the description of the type in all structural details and notably in the genitalia. A coloured drawing from life was made of one specimen, from which the following description of the coloration has been drawn up.

Translucent, pale green with the following deeper-green markings: the rostrum, four curved longitudinal lines on occiput, three spots, flanked by small brown marks, along median line of pronotum, two indefinite rows of spots on lateral lobes, margins of the pleurae, external veins of the tegmina, a mid-dorsal row of spots on the abdomen, dorso-lateral transverse bands, interrupted in the middle, on the margins of the abdominal tergites. The brown markings on antennae and legs are as in the original description, also the crimson marks on the tegmina, but the black blotch on the latter is found to vary considerably in extent. There is a triangular brown median spot at the margin of the ninth tergite and in some specimens there are short, ill-defined, brown marginal lines on the sides of the dorsum of tergites 4 to 8. The femoral and tibial spurs on the fore-legs are greyish dorsally, black ventrally, with a small crimson spot around the base of each. Those of the mid-legs are almost colourless, faintly zoned with crimson, and with a crimson spot around their bases.

The abdomen in life is nearly as long again as it is shown in my figure (*loc. cit.*, Plate XLIX, Fig. 1), which was drawn from a preserved

specimen. Moreover, it is not compressed proximally as shown there but is almost parallel-sided and roughly semi-circular in section. The two long, curved prongs mentioned in the original description in connexion with the genitalia prove to be articulated to the supra-anal plate and are homologous with similar, but much smaller, structures found in other species of the genus.

It is unfortunate that the female of this interesting species is still unknown, the specimen described as a paratype having proved to belong to a different species, D. confusa, described below. It is by no means common, as an aggregate of many days collecting at Labugama, distributed over most months of the year, has resulted in the capture of only four adult specimens.

One specimen was kept alive for ten days and its habits did not differ from those described for the genus (see above p. 3).

Decolya confusa, sp. nov.

Plate I, Figs. 1 and 2 and Plate III, Figs. 5 and 9

Decolya splendens Henry, 1932. (♀). *Ceylon J. Sci.* (B) Vol. XVI, p. 247, Plate XLIX, Figs. 2 and 3.

In describing *D. splendens* I was misled into believing that the male and female specimens before me at the time were the two sexes of the same species because they were from the same locality and agreed fairly well in ambisexual characters and in size. Since then, however, five male and two female Decolyas have been collected at Labugama which differ markedly from the male of *D. splendens* but are obviously conspecific with the described female. The new species was found in exactly the same kind of situations as *D. splendens* and its feeding and resting habits are in general the same; it is remarkable that two species so closely related should occur in the same area!

♂. Smaller and more slenderly built than *D. splendens*, and differently coloured. Antennae inconspicuously noded with brown. Fastigium of vertex longer than in *D. splendens*, reaching to about half the length of the first antennal joint, whereas in the latter it reaches only to about the basal third. It is cylindrical, tapering, and bluntly pointed. The eyes are much smaller than in *D. splendens*. Face very reclinate. Pronotum somewhat narrowed anteriorly, its width equal to three quarters of its length, its fore and hind margins truncate, the former minutely raised in the middle; the transverse sulci fairly well marked; the lateral lobes horizontally expanded as in other members of the genus. Sternites as described for the genus (see p. 6).

Tegmina as long as, or slightly longer than, the pronotum; of the same general shape as those of *D. splendens* but rather narrower. Wings practically absent.

Legs long and slender. The spur formula of the fore- and mid-legs is the same as in all the other described Ceylonese species of the genus. (See pp. 4 and 5); the mid femora bear two basal post-axial spines (in series with the one on the trochanter), of which the distal is half, or less, the length of the proximal; the hind femora bear 10 to 13 acute spines on the lower external carina.

Genitalia. The tenth tergite is transverse, deeply cleft in the middle forming two angular lobes, rounded at their apices, which curve downwards around the inner side of the bases of the cerci. The supra-anal plate is small, rounded, longitudinally sulcate, fitting into the cleft of the tenth tergite; its articulated appendages are mere rounded lobes, one on each side of the anus. The titillator (Plate I, Fig. 2) arises as a flattened rod which divides inside the genital cavity to form two long processes suggestive of the furcula of a fowl. Each of these processes is slightly flanged on its externo-proximal half, distally cylindrical and parallel-sided to the apex, which is rounded. The cerci are strongly bowed near the base where they are slightly broadened and compressed; their distal three-fourths are less strongly curved, nearly cylindrical, with no internal flange and no expansion at the tip, which is roundedly pointed. The sub-genital lamina is broad, with rounded-convex sides, broadly truncate or shallowly emarginate between the styles, which are wide apart.

Coloration. In life, a pale, translucent green. A median stripe of deeper green runs the whole length of the body from the vertex to the tenth tergite; a similar stripe, more or less sinuous, runs from the inner margin of each eye throughout the length of the body, crossing the pronotum about midway between its median line and its lateral margin; a sub-marginal line on the sides of pronotum; broken lines at the ventral borders of the pleurae; ill-defined lines on the fore- and mid-legs, and distinct dorsal and lateral lines on the hind femora; are of the same colour. The eyes, in life, are yellow with a red dorsal spot in the day-time, changing to deep purplish brown all over at night. The auditory bullae on fore tibiae are not marked with brown or fuscous; the distal margins of the pulvilli of the third tarsal joints are dark brown. The fore femoral and tibial spurs are pale translucent-grey, darker at the tips; the mid femoral and tibial spurs are crimson in the middle on the ventral side and have dark-brown apices. The tegmina are greenish hyaline with the outer veins stronger green. The

tympanal area and an apical spot are bright, opaque chrome yellow with part of the thickened, file-bearing vein, and of the speculum, bright vermilion red. In one specimen the disc of the speculum bears a dark-brown blotch. The abdomen has a row of bright, opaque, yellow spots on each side of the median green stripe.

In the pinned specimens, of course, these beautiful colours have largely vanished; the above description has been drawn up from a coloured sketch, which was made from a living individual, and supplemented by reference to the dried specimens, which have retained their pattern to a considerable degree. The delicate beauty, in life, of all the species of *Decolya* must be seen to be appreciated.

♀. Resembles the male in general shape and coloration. The ovipositor is narrow, more strongly curved proximally than distally, its dorsal margin more coarsely serrated and for a longer distance than the ventral. At its ventral base it bears a pair of minute tapering processes similar to those of *D. roseopicta* but smaller. The shape of the eighth tergite and of the sub-genital lamina may be seen in Plate III, Figs. 5 and 9. (*N.B.*—The figure of the ovipositor given in *Ceylon J. Sci.* (B) Vol. XVI, Plate XLIX, Fig. 3, was drawn from a rather shrivelled specimen and is not very satisfactory and so I here present a fresh drawing of this organ.)

Measurements

	♂ mm.			♀ mm.	
Length	13.0	to 15.0 (in life 19.4)	22.5	to 26.0
Length of antenna, about	67.0	to 76.0	...	48.0	to ?
Width of head, including eyes	2.6	to 2.7	...	2.6	to 2.7
Length of pronotum	3.5	to 3.8	...	3.7	
Width of pronotum	2.75	to 2.9	...	2.9	
Length of tegmen	3.7	to 4.0	...	3.0	to 3.1
Length of fore femur	8.5	to 9.2	...	9.0	to 9.3
Length of fore tibia	10.1	to 11.0	...	10.0	to 10.8
Length of hind femur	14.0	to 15.2	...	15.0	to 15.7
Length of hind tibia	18.1	to 19.0	...	18.5	to 19.8
Length of ovipositor (base ventrally to tip)	—		...	10.7	to 11.0
Width of ovipositor, dorso-ventral	—		...	0.95	to 1.0

Material examined. 1 female (described, *loc. cit.*, as *D. splendens*), 22-i-30; 1 male, 26-xii-31; 3 males, 15 to 18-viii-32; 1 male (type) and 2 females, 28-i-33; all were captured at Labugama, in the bamboo undergrowth. The type, with another male and a female will be presented to the British Museum (Natural History).

Habits, &c. Several specimens were kept alive in captivity, one female surviving for two months. Their habits did not differ from those of other members of the genus. On several occasions individuals were seen to capture flies by a rapid sweeping action of their fore-legs which they used with great dexterity for this purpose.

Decolya mousakandae, sp. nov.

Plate II, Figs. 6 to 9 and Plate III, Fig. 2

In size, habitus, and general structure this species very closely resembles *D. roseopicta* Uvarov, of which, when the first specimen came to hand, I was inclined to regard it as a variety. The receipt of further specimens of both sexes, however, has decided me to describe it as a new species. It may readily be distinguished from *D. roseopicta* by (1) the very small size, in both sexes, of the tegmina, which reach little, if anything, beyond the metanotal margin; and (2) the genital characters. The coloration is as described above (p. 8) in *D. roseopicta* but the crimson-brown marks seem to be stronger and there is an additional double row of spots along the middle of the dorsum of the abdomen, as shown in Plate II, Fig. 6.

The ♂ genitalia differ from those of *D. roseopicta* principally in the form of the appendages of the supra-anal plate and the titillator; the former are broad plates projecting obliquely backwards into the genital cavity and each bearing on its ventral margin a long, peg-like projection (see Plate II, Fig. 9). The titillator (which is omitted from the figure cited) takes the form of a pair of very long, slender, cylindrical rods, very slightly clavate and recurved at the apex, which unite far inside the genital cavity; in the specimens before me these rods each lie just mesad to the pegs on the appendages of the supra-anal plate. The cerci are much like those of *D. roseopicta* but the flange on the inner ventral side is smaller and the tips are broader and more deeply gutter-shaped. The sub-genital lamina is as shown in Plate II, Fig. 8.

The ♀ genitalia resemble those of *D. roseopicta* in most respects, but the form of the eighth tergite is different as may be seen by comparing Figs. 1 and 2 of Plate III. The deep vertical furrow which divides the ventral portion of this tergite in *D. roseopicta* into a proximal gibbosity and a distal, obliquely-projecting flange is represented only by a very slight concavity. The two small tapering processes on the base of the ventral valves of the ovipositor in all specimens of *D. roseopicta* are quite absent in *D. mousakandae*.

Measurements

	♂ mm.	♂ mm.	♀ mm.	♀ mm.
Length	13.0	14.0	22.2	22.7
Length of antenna, about	55.0	50.0	55.0	50.0
Width of head, including eyes	2.7	2.7	2.75	2.7
Length of pronotum	3.1	3.2	3.3	3.05
Width of pronotum	3.0	3.0	3.0	3.0
Length of tegmen	1.9	1.6	2.0	1.3
Length of fore femur	6.4	6.9	6.9	6.75
Length of fore tibia	7.8	7.7	8.0	8.0
Length of hind femur	10.9	11.3	12.0	12.0
Length of hind tibia	13.4	13.1	14.0	13.3
Length of ovipositor (base ventrally to tip)	—	—	10.75	10.8
Width of ovipositor, dorso-ventral	—	—	1.25	1.25

Material examined. 1 male, 5-v-33; 1 female, 24-v-33; 1 male (type), 18-viii-33; 1 female, 7-i-34; 2 males, 21-ii-34; all captured by Mr. Phillips at Mousakanda Estate, Gammaduwa, at an elevation of about 2,400 feet—*i.e.*, over 1,000 feet lower than the places where he finds *D. roseopicta.* I understand that all the specimens were taken within a radius of a few yards.

The type, another male, and a female will be presented to the British Museum (Natural History).

Decolya phillipsi, sp. nov.

Plate II, Figs. 1 to 5 and Plate III, Figs. 3 and 10

Closely allied to *D. roseopicta* Uvarov, but larger, being intermediate in size between it and *D. splendens* Henry, and differing strongly in the genitalia.

♂. Antennae slightly noded. Head, eyes, &c., very similar to those of *D. roseopicta* but the fastigium of vertex is relatively somewhat shorter and stouter. Pronotum very nearly as broad as long, truncate and very slightly emarginate medially, both in front and behind. Tegmina shaped as in *D. roseopicta* but apically more produced and rounded. Anal tergite transverse, 'with the postero-lateral angles rounded, deeply and angularly excavated medially for the reception of the small, circular, supra-anal plate. Articulated to each side of the latter there is a chitinous appendage, consisting of a broad base and a bowed and somewhat flattened process shaped as in the figure. (Plate II, Fig. 5); in life these appendages are freely moveable. The

titillator is in the form of a rod which passes between the supra-anal appendages and bifurcates into two stout, cylindrical, slightly-curved arms which are grooved on their inner sides; the whole organ being in the form of a y. The cerci are swollen at base, then sharply bowed outwards, then evenly curved to the tips; they taper gently and are slightly twisted, but have no internal flange; in profile their curvature is feebly sigmoid. The tips are flattened, pointed, and slightly spatulate; the shape is best understood from the figures (Plate II, Figs. 1 and 5). The sub-genital lamina is broad, curved on the sides, deeply and narrowly excavated between the styles which are close together (Plate II, Fig. 4).

Coloration. Pale green, indefinitely marked with a slightly deeper green. There are some brownish-crimson lines on the disc of the pronotum, arranged as shown in Plate II, Fig 1. The file-bearing vein on the left tegmen is yellowish, suffused with brownish red. The tympanal area of the left tegmen is fuscous, with a hyaline spot, of varying size, in the centre of the speculum; the vein which surrounds the latter is reddish. The distal portion of the anal field of the tegmina is yellow and the postero-internal margin is diffusely lined with brownish crimson. The latero-dorsal margins of the abdominal segments are faintly lined with dull crimson. The ventral surface of the fore-femoral spurs is blackish and the mid-femoral and tibial spurs are more or less crimson-pink. The dorsal surface of the auditory bullae on fore tibiae is slightly brown. (*N.B.*—These colours are described from fresh specimens and they will undoubtedly fade in preserved examples.)

♀. Resembles the male in size, colour, marking, &c., and in all ambisexual characters. Her tegmina are oval and about three quarters of the length of the pronotum; they are green with a few diffuse intervenular spots of crimson-brown on the disc and a narrow, apical margin of the same colour (Plate II, Fig. 3). The ovipositor is long, brown at the extreme apex, with the dorsal valves practically smooth, the ventral valves minutely serrate for a short distance from the tip. The margin of the eighth tergite is deeply excavated at the sides, its ventral area being concave and somewhat lobately produced posteriorly. The ninth tergite is somewhat swollen ventro-laterally, its posterior margin slightly retracted and turned up. The cerci are tapering, cylindrical. acuminate, slightly curved inwardly. The sub-genital lamina is transverse, swollen and projecting, slightly medially furrowed. The two minute tapering processes found on the ventral base of the ovipositor in *D. roseopicta*, *D. confusa*, and *D. elegans* appear to be quite absent. (See Plate III, Figs. 8 and 10.)

Measurements

	♂ mm.			♀ mm.		
Length	13.8	to	15.0	24.3	to	27.7
Width of head, including eyes	2.95	to	3.0	3.0		
Length of pronotum	3.6	to	3.7	3.8	to	4.0
Breadth of pronotum	3.3	to	3.5	3.3	to	3.5
Length of tegmen	4.4	to	4.7	3.0	to	3.3
Length of fore femur	6.8	to	7.0	7.1	to	7.3
Length of fore tibia	7.5	to	8.0	8.0	to	8.3
Length of hind femur	12.0	to	12.75	12.5	to	13.0
Length of hind tibia	13.0	to	13 75	14.3	to	15.0
Length of ovipositor (base ventrally to tip)	—			13.0		
Width of ovipositor, dorso-ventral	—			1.3	to	1.4

Material examined. 8 males and 4 females captured by Mr. Phillips on Mousakanda Estate, Gammaduwa, at an elevation of about 2,800 feet, in May and June, 1933.

The type and some other specimens of both sexes will be presented to the British Museum (Natural History) on publication of this paper.

Decolya elegans, sp. nov.

Plate I, Figs. 3 to 5 and Plate III, Fig. 4

This species is nearest to *D. confusa* Henry (see above p. 10) which it resembles in size and general facies but differs in a number of features, and notably in the structure of the ♂ and ♀ genitalia. Like *confusa*, it is a slender species with long limbs. In some details of coloration it approaches *splendens* and *petiyagallae* (Henry,, 1932) but is less robustly built than them.

♂. Antennae noded with brown, but not so conspicuously as in *splendens;* their first joint somewhat similar to that of *confusa* but relatively longer and more slender than in *phillipsi* or *roseopicta*. Eyes prominent and globular. Fastigium of vertex fairly long, evenly tapering, bluntly pointed. Pronotum shaped much as in *confusa* but rather more convex in transverse section; much longer, relatively than that of *splendens, roseopicta* or *phillipsi;* its fore margin distinctly emarginate with scarcely a trace of the minute median projection of *confusa*. Tegmina larger than in *confusa*, shaped much as in *splendens*, their apices more roundedly produced than in *roseopicta* or *phillipsi*. Sternal structure as in other species of the genus. Limbs long and slender with their armature of spurs and spines as in other Ceylonese members of the genus (see pp. 4 and 5).

Abdomen long and slender. The ninth tergite is broadly truncate in the middle, lobately produced and rounded at the sides. Anal tergite with a strong, almost globular process on each side of the deep excavation which receives the supra-anal plate; the latter is discally dimpled. Attached to the supra-anal plate is a pair of movable appendages shaped like the wings of a pigeon. The external portion of the titillator is a simple cylindrical rod, but within the genital cavity it expands laminately in its dorsal portion on each side, with the ventral portion forming a strong keel. The cerci are cylindrical except at their apices where they are slightly spatulate and with infolded margins. In profile they lie in the same plane almost throughout but in dorsal view they are strongly bowed near the base, then gently curved, and slightly more strongly curved towards the tips which are truncate or minutely bifid. The sub-genital lamina is broad, semicircularly excavated between the short, ovate styles. These details are illustrated in Plate I, Figs. 3 to 5.

Coloration. In general, of a very bright, pale green with rather indefinite spots and bands of richer green distributed as shown in Plate I, Fig. 5. Eyes, in life, yellow with a dorsal spot of vermilion. At night, or during periods of forced activity in the daytime, they change to dark purplish-brown all over. The dorsum of the auditory bulla on fore tibia is fuscous, as is also the distal extremity of the hind tibia and the distal margin of the pulvilli of the third tarsal joints. The outer two-fifths of the file-bearing vein in the left tegmen is dark crimson-brown, and a smudge of the same colour extends obliquely across the disc of the tympanal area, enclosing a round blotch of fuscous on the speculum. There is a small blotch of deep crimson at the apex of each tegmen. The spurs on the fore femora are semi-opaque greyish-white dorsally, fuscous ventrally; the spurs of the mid-legs are dark crimson basally, white in the distal half, with a dark spot on the femur or tibia at the base of each, on the proximal side.

♀. In size, build and ambisexual characters resembles the male. Her colour and green pattern conform to the same plan but the fuscous mark on the auditory bulla is very faint. The tegmina bear small, dark crimson suffusions in the region which corresponds to the tympanal area of the male, and distinct, though small, spots at the apices. The fuscous spot at the apex of the hind tibiae is present as in the male.

The ovipositor is shaped as shown in Plate III, Fig. 4. At its ventral base there is a pair of small tapering processes as in *roseopicta* and *confusa*. The ventral margin, of the eighth tergite is produced proximally into a pronounced, rounded lobe somewhat resembling that

of *confusa* but more compressed and not recurved. . The ventral valves of the ovipositor are minutely serrated for their distal third and the dorsal valves are almost imperceptibly serrated for a slightly shorter distance.

Measurements

	♂ mm.	♀ mm.
Length	18.0 (in life)	22.0 (dry specimens)
Length of antenna, about	78.0	75.0
Width of head, including eyes	2.7 to 2.8	2.75
Length of pronotum	3.35 to 3.5	3.3 to 3.5
Breadth of pronotum	3.0	2.85 to 3.0
Length of tegmen	4.7 to 5.0	3.0 to 3.1
Length of fore femur	7.9 to 8.0	7.5 to 8.2
Length of fore tibia	9.3 to 9.6	9.25 to 10.2
Length of hind femur	14 0	13.6 to 15.0
Length of hind tibia	16.2 to 17.2	16.6 to 17.8
Length of ovipositor (base ventrally to tip)	—	8.9 to 9.4
Width of ovipositor, dorso-ventral	—	1.1 to 1.2

Material examined. 1 female, 18-viii-33; 2 males, 25-viii-33; 3 males 29-viii-33; 2 males and 2 females, 19-ix-33; 2 males and 1 female, 19 to 24-xi-33; all from Mousakanda, Gammaduwa, where they were collected by Mr. W. W. A. Phillips who has kindly presented them to the Colombo Museum. The type ♂ (19 to 24-xi-33) and some paratypes of both sexes will be presented to the British Museum (Natural History).

Remarks. All the specimens, with the exception of one female, were captured in an area of a few square yards at an elevation of approximately 3,500 feet, in a different part of the estate from those localities where *D. roseopicta* or *D. phillipsi* are respectively obtained; the exception was taken in a jungle area where *D. roseopicta* is common. This is the fourth species of *Decolya* from Mousakanda (*i.e.*, *D. roseopicta*, *D. mousakandae*, *D. phillipsi*, and *D. elegans*). It seems extraordinary that so small an area—all four species being found within a radius of about a mile—should include four species so closely related, of apparently precisely similar habits, and yet so distinct. The genus *Decolya* would seem to be one which would well repay intensive study by geneticists.

This species is the most delicately beautiful of all the species known to me. Its green coloration has a lovely, fresh quality, while the dark

crimson and fuscous marks detailed above supply a contrast similar in its effect to the ' patches ' with which ladies of fashion in the 18th century were wont to enhance the beauty of their complexions.

CONCLUSION

There is no doubt that many more species of this interesting genus remain to be discovered in Ceylon, and, in fact, the Colombo Museum possesses a single male of one, and a pair of another, undescribed species, taken respectively at Ougaldowa Estate, near Belihuloya, and at Ohiya. Further material of these is awaited before embarking upon a description of them. In the present stage of our knowledge of these insects it does not seem worth while to publish a key to the known species, but it is hoped that further collecting will enable me to do so later on. In the meanwhile it may be remarked that only two species of *Decolya* appear to have been described from localities outside Ceylon, viz., the genotype, *D. visenda*, Bolivar (1900) from Kodaikanal, S. India, and *D. kotoshoensis* Shiraki (1930), from Formosa. The former differs from the Ceylonese species in possessing an extra pair of ' spines ' (*i.e.*, spurs) on the fore femora; 5 pre-axial spurs instead of 4 on the mid-femora and only one post-axial spine; and in genital characters. The latter differs in having its fastigium of vertex distinctly sulcate; its meso-sternal pair of processes long and perpendicular as well as the prosternal pair; its front coxae without a spine; its mid tibiae, dorsally, with only the pre-apical spine, &c.

The discovery by Shiraki of a species of *Decolya* in Formosa is of great interest and vastly extends the known range of the genus. It is highly probable that want of collection is responsible for the apparent discontinuity of distribution, rather than absence of the genus from the countries intervening between Ceylon and Formosa, and it is much to be hoped that collectors will make special search for members of this genus in the Oriental Region generally. As already indicated, they are to be found in forests where there is a heavy rainfall, and the best way to obtain them is by beating the branches of shrubs and low trees over a butterfly-net. For the benefit of collectors I offer the following notes on the technique which I have found most satisfactory for preserving these delicate Tettigoniidae; for the ordinary method of ' pinning and drying ' quite fails to give satisfactory results owing to the shrinkage, distortion and discoloration which ensue on this slipshod system. The insect, as soon as it has been killed in the cyanide bottle, is carefully eviscerated, by means of fine, curved forceps, through a ventral slit, made with fine scissors, extending from ventrite 1 to about 7. A drop of 5 per cent. formol is now inserted by means of a

pipette and is circulated to all parts of the insect's interior by probing with the forceps. When the formol has coagulated the internal tissues —which it does almost instantaneously—it will be found that considerably more of the insect's soft parts can be extracted. It is important to remove as much as possible of the fat body, for, if this is left in, it appears to go rancid in time and contributes not a little to future discoloration; at the same time care must be exercised to avoid disturbing the very delicate pigment layer which lies just internal to the cuticle. For the best results it is essential at this stage to stuff the abdomen, as otherwise it will shrink and shrivel badly in drying. As may be imagined, this taxidermic process, with fragile creatures 1 inch or less in length, is by no means an easy one. The best way to proceed is to roll a tiny pledget of cottonwool between the finger and thumb until it forms a firm, long-oval mass about ¾ths the length of the abdomen. Holding the insect dorso-ventrally by the genitalia, one end of the pledget of wool is inserted into the slit in the abdomen by means of the fine forceps and pushed into the thoracic cavity until the other end can be inserted into the posterior part of the slit, when the forceps may be used to coax it backwards until it fills the abdomen satisfactorily. If the pledget of wool is neither too large nor too small, the operation, with a little practice, is not unduly difficult. The sides of the slit may be drawn together over the wool and the genitalia restored to their proper positions by means of a pin, and the job is complete. The insect should now be pinned with a silver point through the meso-thorax immediately behind the pro-thorax and between the bases of the tegmina. It is of great advantage to pin the insect down flat on the surface of a papered peat block, and then to arrange its legs in extended position and peg them down with fine pins, ·before the formalin has time to set them too firmly. After a day or two it may be removed and pinned on to a pith stage and will be found to retain its form almost perfectly and its colour to a satisfactory degree.

Needless to remark, a good binocular dissecting microscope very greatly facilitates the intricate operations detailed above.

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EXPLANATION OF PLATES

PLATE I

Fig. 1.—Decolya confusa, sp. nov. ♂ × 5
Fig. 2.— ,,   ,,   ,,   titillator, dorsal × 20
Fig. 3.—Decolya elegans, sp. nov. ♂ × 5
Fig. 4.— ,,   ,,   ,,   ♂ sub-genital lamina × 11
Fig. 5.— ,,   ,,   ,,   ♂ genitalia, postero-dorsal aspect × 14
(N.B.— In this figure the titillator is strongly fore-shortened)

PLATE II

Fig. 1.—Decolya phillipsi, sp. nov. ♂ × 5
Fig. 2.— ,,   ,,   ,,   ♂ head and pronotum in profile × 5
Fig. 3.— ,,   ,,   ,,   ♀ tegmina × 5
Fig. 4.— ,,   ,,   ,,   ♂ sub-genital lamina × 8
Fig. 5.— ,,   ,,   ,,   ♂ genitalia, dorsal × 8
Fig. 6.—Decolya mousakandae, sp. nov. ♂ × 5
Fig. 7.— ,,   ,,   ,,   ♀ tegmina × 5
Fig. 8.— ,,   ,,   ,,   ♂ sub-genital lamina × 8
Fig. 9.— ,,   ,,   ,,   ♂ genitalia, postero-dorsal aspect × 14

PLATE III

Fig. 1.—Decolya roseopicta Uvarov, ovipositor ∨ 6
Fig. 2.—Decolya mousakandae, sp. nov., ovipositor ⋎ 6
Fig. 3.—Decolya phillipsi, sp. nov., ovipositor ⋎ 6
Fig. 4.—Decolya elegans, sp. nov., ovipositor × 6
Fig. 5.—Decolya confusa, sp. nov., ovipositor × 6
Fig. 6.—Phisis kelletti Henry, ovipositor × 6
*Fig. 7.*—Decolya roseopicta Uvarov, ♀ genitalia, ventral × 8
Fig. 8.—Decolya ,,   ,,   egg, from ovary, × 8
Fig. 9.—Decolya confusa, sp. nov., ♀ genitalia, ventral × 8
Fig. 10.—Decolya phillipsi, sp. nov., ♀ genitalia, ventral × 8
Fig. 11.—Phisis kellotti Henry, ♀ genitalia, ventral × 8
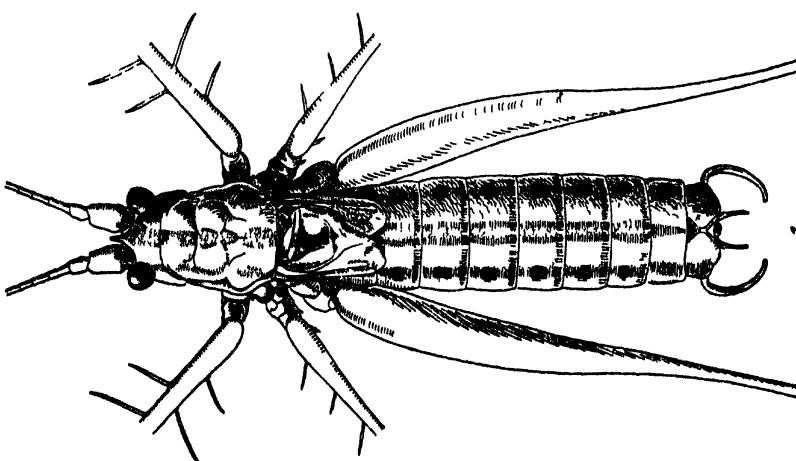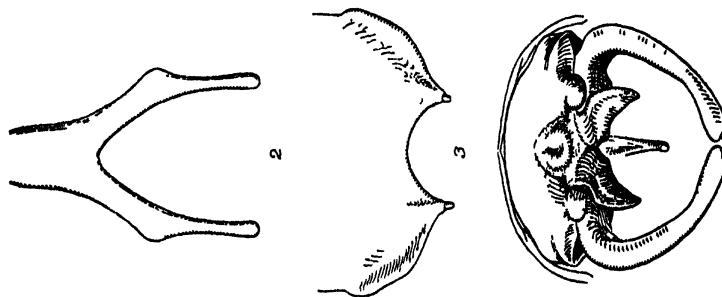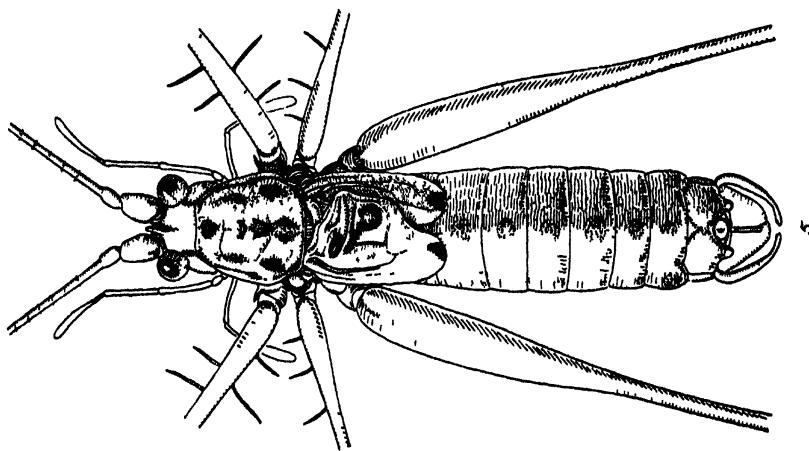
Figs 1, 2   Decolya confusa, sp. nov.
Figs. 3, 4, 5.   Decolya elegans, sp. nov.

PLATE II
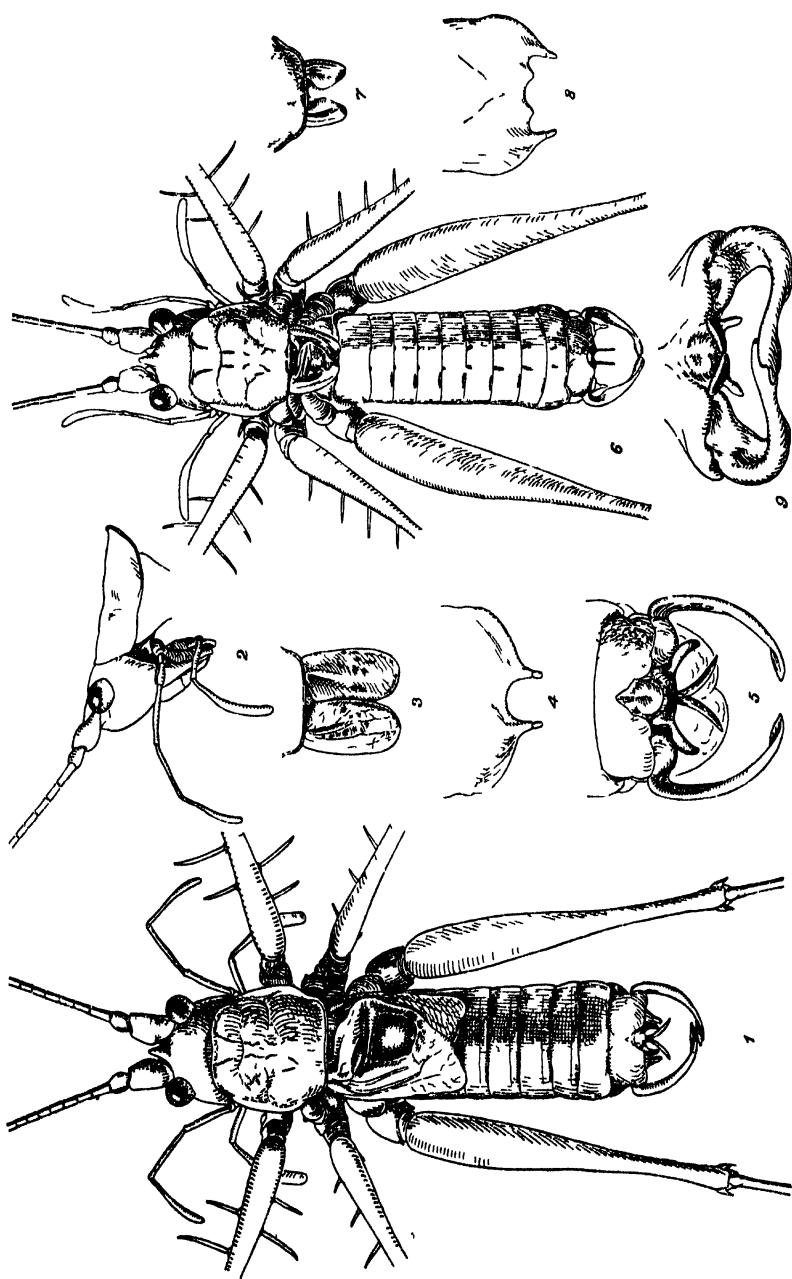
Figs 1 5 *Decolya philipsi, sp nov*
Figs 6 9 *Decolya mousakandae, sp nov.*

Female genitalia of *Decolya* spp and *Phisis kelletti*
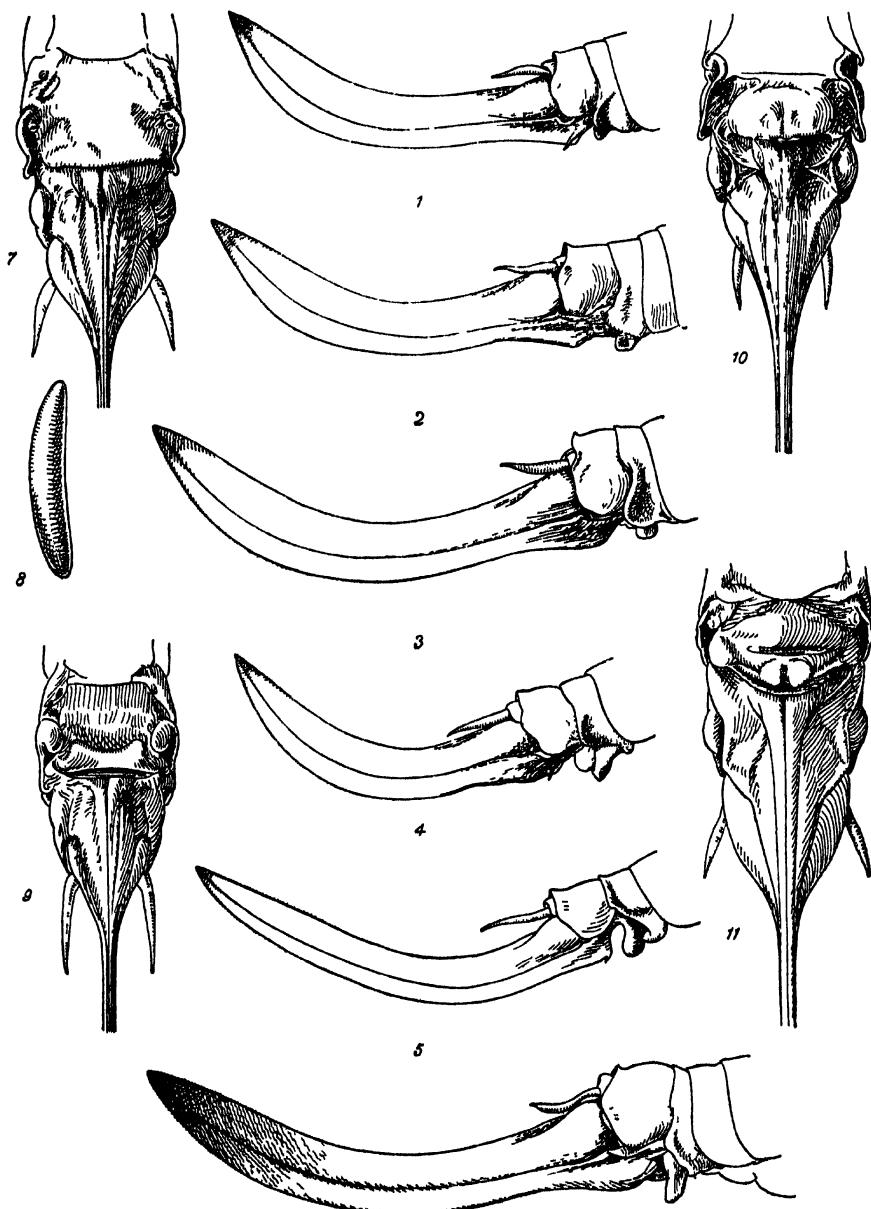
A Monograph on the Purple-faced Leaf-monkeys (Pithecus vetulus)

BY

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(With Seven Text Figures and Six Plates)

PART I—GENERAL

With the exception of an anomalous Baboon (*Cynopithecus*) in the island of Celebes, all the monkeys of Asia belong to one of two categories. One, easily recognized by the presence of cheek-pouches, comprises the Macaques. The remainder, lacking cheek-pouches, but highly specialized in other ways, form a large series (over thirty species, many with several local races) all agreeing in their exclusively vegetarian diet. This great group has until recent years comprised the genus *Semnopithecus*,—a name given by Desmarest (1822) as a Latinized form of F.Cuvier's (1821) *Semnopithèque*. The recent changes in nomenclature and the splitting up of the original genus are dealt with below. For reasons also considered below, the name ' Leaf-monkeys ' is the best English equivalent for this large group.

Ceylon has its share of both types of Asiatic monkeys. The Macaques are represented solely by the Toque Monkey (*Macaca sinica* L.). Leaf-monkeys, on the other hand, are very well represented in the island. They belong to two main types. Those in the drier part of the island resemble the Entellus Monkey (*P.e.entellus* Dufresne) of Northern India, of which they are now considered to be merely a local race (*P.e.thersites* Blyth). This form is easily recognized by its slender build, light grey colour, and generally also by the presence of a distinct tuft or crest on the crown. It agrees, moreover, with all the mainland races of the same species in having a radiating arrangement of the hair on the frontal region just posterior to the brows.

The remaining Ceylonese Leaf-monkeys are of a different type. Together with a single mainland form ranging over the Malabar tract of Southern India, these animals differ from those of the Entellus type in having no frontal whorl, the hair on the crown being semi-erect and cranio-caudad in direction. They are, moreover, more heavily-built animals and are generally dark in colour, though frequently showing albinistic tendencies in individuals. Anderson (1878), Blanford (1888) and, more recently, Pocock (1928) all subscribe to the view that the last-named monkeys are all very closely related to one another, though only Pocock has gone so far as to classify them as geographical races of one and the same species.

The present paper is to be regarded as a revision of the races of this species whose name, for reasons considered hereunder, is the Purple-faced Leaf-monkey, *Pithecus vetulus* (Erxl.).

NOMENCLATURAL NOTES ON THE LEAF-MONKEYS WITH SPECIAL REFERENCE TO THE PURPLE-FACED LEAF-MONKEY *PITHECUS VETULUS* (ERXL.)

The scientific nomenclature of most groups of monkeys has in recent years suffered many and drastic changes. This has led in numerous instances to a state of utter confusion at the present time. In no group is this confusion more evident than in the Oriental group formerly known by the generic name *Semnopithecus* Desmarest; and of all the members of this genus the Ceylonese animal formerly referred to as *S.kephalopterus* Zimmermann or as *S.vetulus* Erxleben, and known locally as the Black Wanderoo or Purple-faced Monkey, is perhaps the most troublesome in th's respect. To make matters worse, this species is the type of its genus and the type-specimen (a lectotype) is a partial albino! It is small wonder, in face of difficulties of this sort, that an authority such as Wood-Jones (1929) finds it more convenient to discuss monkeys of any sort under their English names rather than their supposedly scientific ones. No doubt the nomenclature of Primates will ' settle down ' to some sort of order in due time; but it is hard on contemporary naturalists till that ideal state prevails. This is inevitably a slow process, and is made still more so by the action of some systematists who persist in using names which are not accepted by the majority of their fellow-workers.

Let us then first of all settle on a good English name for the monkeys under consideration. All Asiatic monkeys other than Macaques have of recent years been referred to as Langurs or Lungoors). This term, according to Pocock, is the anglicized form of a Hindi word, and strictly refers only to those forms which inhabit the

countries where that language is spoken, *i.e.*, in particular to the well-known Entellus Monkey (*Pithecus e. entellus*) of North India. By many recent writers the name has been extended to include all the monkeys related to this northern species. Other species, notably those of the Burmese and Malayan countries, have been spoken of as Leaf-monkeys,—a name which I propose to adopt for the whole series covered by the generic name *Pithecus* (Geoffroy et Cuvier) (formerly *Semnopithecus* Desmarest). The appellation Leaf-monkey refers to the food-habits of all the members of the group. It is therefore a suitable English name, and thus renders unnecessary the introduction of foreign terms into the list. The only other English term that has been used is ' Sacred Monkeys ', but this is practically synonymous with ' Langur ' and refers strictly only to that form which is actually deified by the Hindus, namely, the Entellus already referred to. The name ' Leaf-monkey ', on the other hand is a wider expression and covers not only the Sacred Monkey or Langur proper, but also the monkeys known in Ceylon as Wanderoos (Sinhalese *vandhura*) and in Malayan countries as Lutongs and Surelis. With regard to the anglicized Sinhalese name Wanderoo, it is to be remembered that Buffon (1766) confused matters by applying this name erroneously to the Lion-tailed Macaque (*Macaca silenus*) of the Nilgiris, under the mistaken notion that this monkey occurred also in Ceylon and was the same animal as the black Ceylonese monkey mentioned by Ray and since proved to be a Leaf-monkey. As regards the Malayan names it need only be noted that they have never been extended to include forms outside the Malayan region, and are therefore of interest as native names only.

Turning now to generic names for the Leaf-monkeys it may first be noted that the classical writers on the group have, almost without exception, adopted the name *Semnopithecus* Desmarest with the result that this name is the most familiar one. Unfortunately, however, it is not the oldest name. There seems no reason to depart from the suggestion made by Oldfield Thomas (1916) that the term *Pithecus*, E. Geoffroy et Cuv'er should stand for the group under consideration, as it has been amply shown by Allen (1915) and others that Elliot's (1913) usage of this term for the Macaques was quite erroneous. Elliot's application of *Pygathrix* E. Geoffroy to the majority of the Leaf-monkeys was equally untenable. It must be remembered that several of the Leaf-monkeys have in recent times been relegated to separate genera. The first to be split off was the Proboscis Monkey (*Nasalis larvatus*); then came the various Snub-nosed Monkeys (*Rhinopithecus*, *Presbytiscus*, and *Simias*); whilst

the Doucs have now been recognized as distinct under the name *Pygathrix* E. Geoffroy. The term *Pithecus* therefore refers to the forms remaining after separation of the above.

Although the Entellus Monkey or True Langur (*Pithecus entellus entellus* Dufresne) of Northern India is the most familiar and best known member of the genus, yet this animal was not the first to become known to science or to receive a scientific name. This honour apparently belongs to a monkey from Ceylon first mentioned by John Ray in 1693. The first scientific name given to a Ceylonese monkey other than a Macaque was *Simia veter*. This was applied by Linnaeus in 1766 to an animal described by two of his predecessors J. Ray, (1693) and M. J. Brisson (1762). As Brisson's account is copied from that of Ray, only the latter's description need concern us. According to quotations given by Thomas (1916) and by Hinton (1923) Ray described at least two monkeys from Ceylon, and neither of these were Macaques. The description quoted by Thomas runs as follows:—*Simia alba seu incanis pilis, barba nigrâ promissa, ex Zeylona; elewandum Zeylanensibus.* The native name is undoubtedly a corruption of the Sinhalese *elli wandura* or *anglicè* a 'grey Leaf-monkey', although the description itself relates to a white, *i.e.*, albinistic specimen of this Wanderoo. The quotation is given by Thomas as from Ray's ' *Synopsis animalium quadrupedum* ', p. 158, 1693.[1] Hinton's quotation is also from page 158 of the same work, and runs as follows:—*Cercopithecus niger, barba in cana promissa, wanderu Zeylanensibus. Ejusdem musei* (i.e., *D. Robinson è Museo Leydensi*). The two descriptions obviously refer to very similar animals, either the same or very closely related species, but the first referred to an albino and the latter to a normal specimen. It appears to be universally accepted that it was to Ray's white monkey that Linnaeus (1766) gave his name *Simia veter* (*vide* M. W. Lyon, 1915; O. Thomas, 1916; R. C. Wroughton, 1918). Linnaeus does not seem to have labelled the black monkey, which thus did not receive a name till 1777 when Erxleben called it *Cercopithecus vetulus*. Ray's white monkey is therefore the earliest animal described as representing the Purple-faced species, for it is only in this species of Wanderoo that albinism is known to occur in Ceylon. Ray's specimen was probably an albinistic individual of one of the low-country races of the species, either *nestor* or *vetulus*, but it is impossible to say which, because there is no specimen extant to testify to Ray's description, and the description itself is insufficient. The name *veter* therefore falls as a specific name, and must be treated as a *nomen nudum*.

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[1] Thomas's reference erroneously gives 1793 as the date of Ray's work.

In 1777 Erxleben redescribed the same two monkeys as were mentioned by Ray. The white one, mentioned first, he named *Cercopithecus senex*, and for the description he relied on the account given by Robert Knox (1681) of ' another sort of Monkey milk-white both in body and face ' which the latter had observed during his imprisonment in the hills of Central Ceylon. In some respects this differs from Ray's description, for in Ray's animal the face was normally coloured. Knox's animals may therefore have been complete albinos, or else were badly described, which is more likely. They were probably albinistic specimens of the Bear Monkey, or of a form intermediate between it and one of the lowland races. Again, however, we are uncertain, as no specimen exists to support Erxleben's description. It must be mentioned however, that in 1876 Hermann Schlegel of Leyden chose a type to represent Erxleben's *senex*. This was an albino brought from Ceylon by his countryman C. J. Temminck at the beginning of the nineteenth century, and placed in the Leyden Museum. The specimen is said to be still in Leyden, and was seen there by Blanford, who said it was comparable in size with the Bear Monkey. In all probability therefore this animal is the same as those mentioned by Knox, but as that is uncertain, we cannot be sure that Schlegel's *senex* is the same as Erxleben's. All writers seem to be agreed that the Leyden specimen is indeterminable, as no definite locality is given. In any case it is probably by now too old and worn for anyone to give an opinion. The specific name *senex* (either Erxleben's or Schlegel's) for the Purple-faced Monkeys must also therefore be dropped as a *nomen nudum*. There is no justification in reviving this name as Pocock did in his revision of these monkeys in 1928. Pocock took the hills of Central Ceylon as the type locality on the strength of Kelaart's (1852) description of a white monkey from Matale. Kelaart's animal was described under the name of *Presbytis albinus*, and all authorities have synonymized this with *senex*, but, as we are uncertain exactly what *senex* stands for, this attitude cannot be adopted, and so Matale must fall as a type-locality.

These uncertainties concerning *veter* and *senex*, however, are not shared by the black monkey described by Ray and Erxleben. The latter was the first to name this form, which he called *Cercopithecus vetulus* in 1777, giving *senex* page precedence only. This black form can only be the animal confined to the south-western coastal tract of Ceylon, south of the Kalu-ganga. After all, this is the most likely race of Purple-faced Monkey to have been obtained during the Dutch occupation of Ceylon, when Galle was the chief port of the island.

Vetulus is therefore the earliest name given to a Purple-faced Monkey from Ceylon that is identifiable from the description,—for here again no type exists to support Erxleben's name. This name is therefore the correct specific name and the form found in the Galle district must be regarded as *Pithecus vetulus vetulus*.

THE CLASSIFICATION OF THE LEAF-MONKEYS OF THE GENUS *PITHECUS*, WITH REMARKS ON THE STATUS OF *P.VETULUS*

Even after removal from the main genus of such outstanding forms as the Proboscis Monkey (*Nasalis*), the Snub-nosed Monkeys (*Rhinopithecus*, *Presbytiscus*, and *Simias*) and the Doucs (*Pygathrix*) the remaining Leaf-monkeys (*Pithecus*, *sensu stricto*) form a very heterogeneous assemblage, and an unwieldy one from point of numbers. Most of the authorities who have revised the group have endeavoured to find affinities enabling them to divide the series into minor groups. To some of these subgeneric names have from time to time been given. The first monographic revision was that of Anderson (1878). Although Pocock (1928 *a*) criticizes Anderson's account as not showing any true appreciation of the mutual affinities, this is certainly untrue in some instances, and especially in the case of the monkeys concerned here. Anderson was clearly aware of the close relation existing between the Ceylonese animals then known by the specific names *cephalopterus*, *senex* and *ursinus*, and also of the affinity shown by these forms to the Indian animal then called *johnii* (see pages 23 and 24 of his monograph). Anderson went so far as to suggest that these monkeys might all be considered as races of one and the same species. In this he was following Muller and Schlegel (1839-44) who regarded *johnii* as a climatic variant of *cephalopterus* (i.e., *vetulus*). Blanford (1888) followed Anderson's arrangement implicitly, as did also Forbes (1895) except that the latter definitely regarded *senex* as a variety of *cephalopterus*. Elliot (1913) did not simplify matters by the division of the genus into six groups and the introduction of subgeneric names for these groups. His groupings were badly arranged and their component species in the main badly chosen, showing little regard for the true affinities. There is one respect, however, in which Elliot seems to have struck a correct note, and that is in the recognition of the relationship between the different types of the Purple-faced Monkeys, including the Malabar form *johni*, and in the separation of this series from all the other members of the genus. Elliot used his subgenus *Presbypithecus* for this series, a name which might stand were it not for the fact that *P.vetulus* is the genotype, and as such demands a subgeneric name

identical with that of the genus,—if subgenera are to be recognized at all. The latest reviser of the genus, Pocock (1928) has evolved a classification of the Leaf-monkeys based on the coloration of the new-born young. According to his scheme there are three well-marked groups of these monkeys as follows:—

(i) The *Entellus* group in which the new-born young is uniformly dark brownish black.

(ii) The *Pyrrhus* group with new-born young uniformly golden or reddish-orange.

(iii) The *Aygula* group with new-born young parti-coloured.

This scheme in all probability represents the most natural arrangement hitherto achieved, but it is open to the criticism that it is based on the examination of too small a number of specimens to be absolutely trustworthy. Referring to the *entellus* group which chiefly concerns us here, it is to be noted that Pocock assumes that the neonatus of all the forms ascribed to the group is uniformly black or dark brownish-black. He admits having evidence of this being the case only in *P.entellus dussumieri, P.e.achates,* and in *P.senex johni.* It is on this slender basis that Pocock unites the *senex* (i.e., *vetulus*) series with the *entellus* series to form one group. As far as *johni* is concerned it may be added that, as the adult is almost wholly black, it is not surprising that the new-born is black also. But it is gratuitous to assume that the same state of affairs occurs in the lighter-coloured Ceylonese races of *vetulus* As a matter of fact this is not the case, as shown hereafter, so that Pocock's grouping of the Leaf-monkeys falls on this point at any rate. It is true that his scheme is in some instances supported by other criteria than the colour of the new-born. Thus he quotes cranial characters, as well as colour of the adult in support of the main divisions mentioned above; but there are no such corroborative characters serving to strengthen the affinity of the *vetulus* monkeys with the *entellus* series. In fact, most of the evidence points the other way. Pocock himself (1928 *b*) freely admits that in cranial characters the *vetulus* series approaches more closely to the *pyrrhus* group than to the *entellus* group and, as will be amply shown hereafter, other characters support this view. Anderson and Forbes, moreover, state in discussing *johni* that it is nearly allied to *obscurus,* which is one of the outstanding members of the *pyrrhus* group.

Taking the above circumstances into consideration it seems advisable to split off the Purple-faced Monkeys from alliance with Pocock's *entellus* group and to make of them a separate group, in some ways

intermediate or leading to the *pyrrhus* group. For the *entellus* series.
Elliot's usage of *Semnopithecus* as a subgenus is applicable. For the
vetulus group his *Presbypithecus* is not available, for this is the type-
series of the genus, and the subgeneric name must be the same as
that of the genus, *i.e.*, *Pithecus*.

The subgenus *Pithecus* therefore comprises a single species, *P.
vetulus*, the Purple-faced Monkey, but this can be resolved into the
following five local races : —

1.	*P.vetulus vetulus* (Erxl.)	... The South-western Lowland Purple-faced Leaf-monkey or Black Wanderoo
2.	*P.v.nestor* (Bennett)	... The Western Lowland Purple-faced Leaf-monkey, True Wanderoo of Tennent or Dusky Wanderoo
3.	*P.v.monticola* (Kelaart)	... The Highland Purple-faced Leaf-monkey, Bear Monkey or Great Wanderoo
4.	*P.v.philbricki* (Phillips)	... The North-eastern Purple-faced Leaf-monkey
5.	*P.v.johni* (Fischer)	... The Nilgiri Purple-faced Leaf-monkey or Malabar Wanderoo

It is a moot point, however, whether the Malabar form (*P.v.johni*)
should not be given full specific rank, since no intermediate types
between it and the Ceylonese forms are known. In such a case the
subgenus *Pithecus* will consist of a Ceylonese and an Indian species,
the former with four local races. This point, however, is a purely
academic one, and does not affect the conclusions discussed in this
paper.

Subgenus **Pithecus** E. Geoffroy et Cuvier

The Purple-faced Monkeys

Heavily built Leaf-monkeys with long, glossy, dark-coloured hair
(except in albinistic individuals); ventral surface as dark as or darker
than the dorsum; hair of crown paler, semi-erect and cranio-caudad
in direction; hair on lower back shorter than elsewhere; face dark
purplish-black. In the skull the brain-case is rounded and compara-
tively smooth. Supraciliary ridges are less prominent than in the
Entelloids (*Semnopithecus*) and the upper margin of the orbit lies on

a plane posterior to the lower. Anterior palatine canals smaller and more rounded than in *Semnopithecus*. Angles of mandible widely divergent.

The neonatus is uniformly dark brownish-black in *johni* only. In all the rest the young are paler than the adults of the same race. They vary from a light silvery grey to leaden grey, and the whiskers, though short at first, are always white from the start. The sacral patch of short hair is not different in colour from the rest of the back in the neonatus, the light patch of the lowland races developing during adolescence.

The subgenus *Pithecus* differs from the Entelloids (subgenus *Semnopithecus*) in having no frontal whorl; in the uniformly dark general coloration of the adult; the light colour of the new-born (except in *P.v.johni*); in the shortness of the hair on the lower back; and in the purplish tinge in the face (as contrasted with the sooty black in the Entelloids). In cranial characters *Pithecus* differs in the small size of the supraciliary ridges, the inclination of the orbital margin, the greater bigonial measurement of the mandible, and, according to Anderson, also in the different shape of the posterior palatine foramina. Of all the Entelloids, that form described as *Semnopithecus hypoleucus* by Blyth (1841) seems to approach *Pithecus* most closely. *Pithecus* on the other hand approaches structurally to the members of the *pyrrhus* group in the cranio-caudad direction of the scalp hair; in the elongation of the side whiskers; and in the general conformation of the skull. Of the *pyrrhus* series the form generally known as *obscurus* seems to come closest to *Pithecus*. *Semnopithecus* on the other hand seems to approach more closely to certain members of the *aygula* group, especially *P.rubicundus* Muller, which has the frontal whorl (*vide* Chasen and Kloss, 1932).

Pithecus vetulus (Erxleben)

The Purple-faced Leaf-monkey

' Another sort of Monkey '	1681	Knox, *Hist. Rel. of Ceylon*, p. 25
Lion-tailed Monkey (vars. β and γ)	1771	Pennant, *Syn. Mamm.*, pp 109 and 110, Pl. CVIII, fig. 2
La guenon à face pourpre	1789	Buffon, *Hist. Nat.*, Suppl. VII, p 8, Pl. xxi
	1809	Latreille, *Buffon's Hist. Nat.* (Sonnini), XXXV, p. 292, Pl. xxvii
Purple-faced Monkey	1793	Pennant, *Hist. Quadr.*, I, p. 199, Pl. xliii. (3 ed.)

Simia veter	1800	Shaw, *Gen. Zool.*, I, pt. 1, Pl. xiii.
	1766	Linn., *Syst. Nat* (12 ed.) I, p. 36
Cercopithecus senex	1800	Shaw, *Gen. Zool.*, I, pt. 1, p. 36
	1777	Erxleben, *Syst. Reg. An.*, p. 24
	1780	Zimmermann, *Geogr. Gesch.*, II, p. 183
	1785	Boddaert, *Elench. An.*, I, p. 57
Cercopithecus vetulus	1777	Erxleben, *Syst. Reg. An.*, p. 25
Cercopithecus kephalopterus	1780	Zimmermann, *Geogr. Gesch.*, II, p. 185
Simia cephalopterus	1785	Boddaert, *Elench. An.*, p. 58
Cercopithecus silenus purpuratus	1792	Kerr, *An. Kingdom*, p. 65
Simia porphyrops	1795	Link, *Beiträge*, II, p. 62
Simia latibarbata	1807	Temminck, *Cat. Syst., Ornith. et Quadr.*, p. 3
Cercopithecus latibarbatus	1812	E. Geoffroy, *Ann. du Mus.*, XIX, p. 94
Cercopithecus leucoprymnus	1825	Otto, *Nova Acta Acad. Nat. Cur.*, XII, p. 505, Pl. xlvi (*bis*)
	1827	Lesson, *Man. de Mammif.*, p. 37
Semnopithecus fulvogriseus	1825	Desmoulins, *Dict. Class. Hist. Nat.*, VII, p. 570
	1834	I. Geoffroy, *Voy. de Bélanger, Zool.*, p. 36 (in part)
	1842	idem, *Comptes Rendus*, XV, p. 719
	1838	Martin, *Charlesworth's Mag.*, (n. s.), II, p. 439
Semnopithecus leucoprymnus	1827	Desmarest, *Dict. des Sc. Nat.*, XLVIII, p. 439
	1828	E. Geoffroy, *Cours de l'Hist. Nat. des Mammif.*, lect. 8, p. 10
	1829	Fischer, *Syn. Mamm.*, p. 16
	1828-30	Lesson, *Oeuvres compl. de Buffon*, IV, p. 22
	1830	idem, *Sp. de Mammif.*, p. 57
	1834	I. Geoffroy, *Voy. aux Indes Orient. Bélanger, Zool.*, p. 36 (in part)
	1851	idem, *Cat. Méthod. des Mammif.*, p. 12
	1840	Wagner, Schreber's *Säugethiere*, Suppl. I, p. 96
	1855	idem, Suppl. I, p. 25
	1839-44	Müller u. Schlegel, *Verhandl.*, p. 59
	1844	Schinz, *Syn. Mamm.*, I, p. 40
	1844	Gervais, *Hist. Nat. des Mammif.*, p. 60
	1856	Dahlbom, *Stud. Zool. Fam. Reg. An.*, pp. 87-89
	1870	Gray, *Cat. Monkeys, etc.*, B. M., p. 14
Macacus silenus var. alba	1829	Fischer, *Syn. Mamm.*, p. 28
Cercopithecus johnii	1829	Fischer, *Syn. Mamm.*, p. 25
Semnopithecus nestor	1833	Bennett, *P. Z. S.*, p. 67
	1840	Lesson, *Sp. de Mammif.*, p. 60
	1844	Waterhouse, *P. Z. S.*, p. 1

Semnopithecus nestor, continued	1855	Fitzinger, *Sitz der Math. Natur.*, XVII, p. 242
Semnopithecus cucullatus	1834	I. Geoffroy, *Zool. Voy. de Bélanger*, p. 38
	1842	idem, C. R., XV, p. 719
	1843	idem, *Arch. du Mus.*, II, p. 541
	1840	Lesson, *Sp. de Mammif.*, p. 59
	1839-44	Müller u. Schlegel, *Verhandl.*, p. 59
	1846	Wagner, Schreber's *Säugethiere*, Suppl. I, p. 98
	1844	Schinz, *Syn. Mamm.* I, p. 41
	1851	I. Geoffroy, *Cat. Méthod. des Mammif.*, p. 13
	1852	idem, *Arch. du Mus.*, V, p. 538
	1854	Gervais, *Hist. Nat. des Mammif.*, p. 61
	1855	Wagner, Schreber's *Säugethiere*, Suppl. V, p. 26
	1856	Dahlbom, *Stud. Zool. Fam. Reg. An.*, pp. 87, 89
	1870	Gray, *Cat. Monkeys, etc.*, B M., p. 14
Semnopithecus johnii	1838	Waterhouse, *Cat. Mamm. Mus. Zool. Soc. Lond.*, 2 ed., p. 5
	1830	Martin, *Charlesworth's Mag.*, II. (n. s.), p. 439
	1841	idem, *Hist. Nat. Quadr.*, p. 487 (in part.)
	1843	Blyth, *J. A. S. Bengal*, XII, p. 169
	1847	idem, XVI, pp. 734, 1272
	1848	idem, *Ann. Mag. Nat. Hist.* II. (n. s.), p. 454
	1843	Gray, *Handlist Mamm.*, B. M., p. 3
	1851	Horsfield, *Cat. Mamm. E. India Co. Mus.*, p. 8
	1878	Anderson, *Anat. & Zool. Res.*, p. 21
	1888	Blanford, *Fauna Brit. India, Mamm.*, p. 33
	1896	Forbes, *Handb. Primates*, II, p. 111
Semnopithecus jubatus	1840	Wagner, Schreber's *Säugethiere*, Suppl. I, p. 305
	1855	idem, Suppl. V, p. 26
	1844	Schinz, *Syn. Mamm.*, I, p. 41
	1851	Horsfield, *Cat. Mamm. E. India Co. Mus.*, p. 14
Semnopithecus cephalopterus	1841	Martin, *Nat. Hist. Quadr.*, p. 482, Pl. 286
	1841	Blyth, *J. A. S. Bengal*, X, p. 839
	1843	idem, XII, p. 169
	1844	idem, XIII, p. 468 (in part), p. 476 (in part)
	1862	Reichenbach, *Vollständ. Naturg. Affen*, p. 99, fig. 239

Semnopithecus   cephalopterus,—
continued

	1867	Hutton, *P. Z. S.*, p. 949
	1876	Schlegel, *Mus. Pays-Bas*, VII, p. 51
	1878	Anderson, *Anat. & Zool. Res.*, p. 22
	1888	Blanford, *Fauna Brit. India, Mammals*, p. 34
	1896	Forbes, *Handb. to the Primates*, II, p. 113
Presbytis cephalopterus	1843	Gray, *Handlist Mamm. B. M.*, p. 4
	1844	Waterhouse, *P. Z. S.*, p. 130
	1847	Blyth, *J. A. S. Bengal*, XVI, pp. 734 & 1271
	1875	idem, XLIV, ex no., p. 11
	1862	idem, *Cat. Mamm. As. Soc., Mus.*, p. 13
	1852	Kelaart, *Prodr. Faunae Zeylan.*, p. 1
	1861	Tennent, *Nat. Hist. of Ceylon*, p. 7, Pl. opp. p. 5, fig. 3 (nec. fig. 1 as marked, which is *thersites*)
Cercopithecus nestor	1844	Templeton, *Cat. Singhalese An.*, p. 1
Presbytis cephalopterus monticola	1849-50	Kelaart, *J. R. A. S. (Ceylon br.)* II, no. 5, p. 321
Presbytis ursinus	1851	Blyth, *J. A. S. Bengal*, XX, p. 155
	1863	idem, *Cat. Mamm. As. Soc. Mus.*, p. 13
	1852	Kelaart, *Prodr. Faunae Zeylan.*, p. 2
	1861	Tennant, *Nat. Hist. of Ceylon*, p. 9
Presbytis albinus	1851	Kelaart, *J. A. S. Bengal*, XX, p. 182
	1852	idem, *Prodr. Faunae Zeylan.*, p. 7
Presbytis cucullatus	1859	Blyth, *J. A. S. Bengal*, XXVIII, p. 283
	1863	idem, *Cat. Mamm. As. Soc. Mus.*, p. 14
Semnopithecus (Kasi) cucullatus	1862	Reichenbach *Vollstand. Naturg. Affen*, p. 101
Vetulus ursinus	1862	Reichenbach, *op. cit.*, p. 128
Vetulus nestor	1862	Reichenbach, *op. cit.*, p. 326, Pl. XXII
Presbytis jubatus	1867	Jerdon, *Mamm. of India*, p. 7
Semnopithecus senex	1876	Schlegel, *Mus. Pays-Bas, Simiae*, p. 53
	1888	Blanford, *Fauna Brit. India, Mammals*, p. 35
Semnopithecus kelaarti	1876	Schlegel, *Monogr. des Singes*, p. 52
Semnopithecus ursinus	1878	Anderson, *Anat. & Zool. Res.*, p. 24
	1888	Blanford, *Fauna Brit. India, Mammals*, p. 36
	1896	Forbes, *Handb. to the Primates*, II, p. 122
Pygathrix (Presbypithecus) cephaloptera	1913	Elliot, *Rev. of the Primates*, III, p. 68
Pygathrix cephaloptera monticola	1913	Elliot, *op. cit.*, III, p. 71
Pygathrix senex (undeterminable)	1913	Elliot, *op. cit.*, III, p. 71
Pygathrix johni	1913	Elliot, *op. cit.*, III, p. 72
Pygathrix ursina	1913	Elliot, *op. cit.*, III, p. 74

.*Pithecus kephalopterus*	1918	Wroughton, *J. Bombay Nat. Hist. Soc.*, XXV, p. 560
Pithecus veter	1918	Wroughton, *loc. cit.*, XXV, p. 561
Pithecus johni	1918	Wroughton, *loc. cit.*, p. 560
Pithecus ursinus	1918	Wroughton, *loc. cit.*, p. 561
	1926	Phillips, *Ceylon J. Sci.* (B) XIII, p. 278
Pithecus vetulus	1923	Hinton, *Ann. Mag. Nat. Hist.*, (9) XI, p. 506
	1926	Phillips, *Ceylon J. Sci.* (B) XIII, p. 273
Pithecus philbricki	1927	Phillips, *Ceylon J. Sci.* (B) XIV, p. 57
Pithecus senex	1928	Pocock, *J. Bombay Nat. Hist. Soc.*, XXXII, p. 498

Sinhalese : *Vandhura*
Tamil : *Mundi*

GENERAL CHARACTERS OF THE SPECIES

Beyond the broad general diagnosis given under the heading of the subgenus *Pithecus* it is almost impossible to give a short characterization of the species *P.vetulus* on account of the very wide range of variation exhibited by specimens from the different climatic zones within its geographical range. This variation is so wide that, as has already been pointed out, former naturalists described the then-known forms as full species. The variations affect more particularly the bodily size, and the length and colour of the hairy coat. In general, highland areas are productive of large forms with profuse hairy coats. Lowland forms are smaller and less heavily clothed with hair, but differ among themselves in colour according to temperature and rainfall. A few remarks must be added at this point with regard to the coat colour of dried skins as this is very misleading, one race at least having been based on skins which show the results of fading. It is most unsatisfactory to depend entirely on museum skins in the delineation of the characters of any Primate, and the confused state of affairs with regard to the present series of monkeys is an example of the evil results accruing therefrom. In coat colour all normal living specimens of *P.vetulus* are either black or some shade of grey, with the exception of albinistic specimens. This, however, does not apply to the crown of the head, which in all forms is definitely brownish. Those forms which have been described as being brown or brownish in general body colour are due to fading. The fading occurs in the living animal in captivity and during the moult, but this old hair is soon replaced by new black or grey hair. In dried skins fading occurs often within a few weeks after preparation, and is, I believe, hastened by arsenical preparations applied to the skin. As a dried skin is useless for almost any other

purpose than obtaining the idea of the colour of its original possessor, and, as other characters than coat-colour are essential in giving even a mere outline of the characters of any species of monkey, it follows that, in the case of the present species, skins may almost be dispensed with as being useless and even misleading.

Bearing these facts in mind, *P.vetulus* may be defined as follows :— a large, heavily-built Leaf-monkey with a long, glossy coat of dark hair more or less uniformly distributed over the trunk and limbs, but with a light brownish area on the crown and nape, and often a paler area on the rump. The hair is long on the sides and on the crown, and shorter on the rump. There are long, laterally-directed whiskers, either the same colour as the crown, or whitish. The naked parts are deep purplish-black, and the pigment is extensively developed on the hairy parts also. Cranium rounded and smooth; muscular and supraciliary ridges poorly developed; plane of orbital opening sloping downwards and forwards.

All the above facts have been known for some time, and are based almost entirely on the examination of ordinary museum material. It is necessary at this stage to go into somewhat more detail with regard to the external and cranial anatomy of this species, and the following account of regions of taxonomic importance is based on examination of living and freshly-dead material only.

EXTERNAL CHARACTERS

1. General Form and Proportions

In general form the Purple-faced Monkey is similar to other members of its genus in having a small, roundish head, large, elongated body, a very long tail and elongated limbs, with the hind limbs in excess of the forelimbs. The hands and feet are extremely elongated, and on the hand the pollex is rudimentary. *P.vetulus* is specially characterized by the extremely disproportionate size of the torso over the head than in the other members of the genus. The head is very small and rounded, with a smooth, ovoid cranium and a small, flattened face, with no tendency to projection of the muzzle. It is joined by a very short and narrow neck to the large, heavily constructed trunk. The head thus appears to be sunk between the shoulders, and this impression is rendered more evident if the gular sac happens to be dilated. This is an extensive appendage of the larynx, which undermines the skin of the throat as far down as the sternum. The greater part of the trunk is formed by the abdomen. The chest is relatively

small, forming a large segment of a small squat cone. The abdomen is large and protuberant, being greater in girth in its upper third, and narrowing rapidly to the level of the iliac crests where it is narrowest. The umbilicus is generally quite evident even in the adult, and is situated nearer to the xiphisternum than to the symphysis pubis. The tail is very long and of practically uniform calibre throughout. The shoulders are set high and are not much prolonged laterally. The upper limbs are long and robust, and the lower limbs still more so. On the medial aspect of the thigh just above the knee there is an elongated deep pocket of triangular form. Here the skin is depressed between the sartorius muscle on the one hand and the edge of the thigh-bone on the other. The skin of this area is almost hairless. Details regarding perineum and hands and feet are given below.

Although details of somatometry are outside the scope of this paper the following rough idea may be given of the general proportions as gathered during the present study.

The head-length (brow-occiput) is one-fifth of the trunk-length (nape-root of tail) and one-seventh to one-eighth the tail-length. The bisacromial breadth is one-quarter more than the maximum cephalic breadth, whilst the bitrochanteric diameter is slightly less than this. The length of the brachium (shoulder-elbow) is roughly the same as that of the forearm (elbow-wrist), whilst the length of the hand is one-quarter less than this. The femur is one-quarter more than the brachium in length, and the crural region measures roughly the same. The foot is one-quarter less than the crus and therefore the same length as the brachium. With the xiphisternal notch as a centre and with a radius equivalent to one-third the length of the brachium a circle can be described which will pass through both nipples and the umbilicus.

2. The Hairy Coat

(a) Hair colour

As already noted the general body colour of the hair in all forms of the Purple-faced Monkey except albinos is black or some shade of grey, and not brown. This main body colour affects all the upper part of the back, the flanks, and the whole of the ventral surface of the body. It likewise occurs on the proximal parts of the limbs on both flexor and extensor surfaces. In the lighter races the distal parts of the limbs, including the hands and feet, are darker than the general body colour, in fact usually black. The lower back with the base of the tail is often lighter than the rest, and this lighter patch may extend for some distance laterally on to the buttocks and thighs. In the

highland races the lighter area is usually absent or at most only feebly marked and not sharply defined from the darker colour of the upper back as it is in the lowland forms. The rest of the tail is but little lighter than the back except at the tip where it may be brownish or even albescent. The only other parts needing special mention in this connection are the crown and nape and the whiskers. The crown in all forms is some shade of sepia brown, becoming lighter on the occiput and nape. The whiskers are most frequently white or whitish, but in *P. v. johni* they are the same colour as the crown. There are usually some short white hairs around the mouth, becoming longer on the chin and throat, from whence laterally they become continuous with the whiskers. A white patch of hair occurs on the pubes in females only.

(b) Length of hair

In general the hair in *P.vetulus* may be described as long and silky. It is longest on the upper back and the flanks, especially on the lower flanks. Naturally the highland races excel the others in this character. The whiskers are always long, being longer in the male than the female. On the crown the hairs are slightly shorter, but they increase on the occiput and nape where they become wavy.[1] On the brows are some stiff bristles, but these are not so long as in the Entelloids. A characteristic patch of shorter hair occurs on the lower lumbar and sacral regions of the back. This patch varies in size, but is, generally of triangular form, with the apex opposite the uppermost lumbar vertebrae, and its base on a level with the root of the tail. Laterally it extends on to the lateral aspect of the thighs for a short distance. It corresponds to the light-coloured area mentioned in the preceding section, but it seems to be present even if there is little or no difference in colour. The tail is clothed with short, close-fitting hairs, except at the tip, where there is often a slight tuft. The hairs of this tuft are not spirally twisted as in the Entelloids. On the limbs the hair is of moderate length, becoming shorter on the forearm and crural region and on the dorsum of the hand and foot. Even here, however, the hairs are generally long enough to hang over the margins of the part.

(c) Direction of the hair tracts

Contrary to the usual findings the hair tracts are better studied in *Pithecus* in the adult than in the new-born, on account of the woolly nature of the fur in the latter. In *P.vetulus* there are a number of

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[1] This character suggests relationship with *P.obscurus* and its allies, in which the occipital and nuchal hairs are thrown into numerous waves resembling the artificial coiffures of some human females.

points in which the hair arrangement differs from that found in the Entelloids. In the first place the stiff, black bristles on the brows are much shorter and less acutely forward in direction than in *P.entellus*. They are longest in the middle and pointed slightly upwards. The lateral ones are directed laterally and upwards. The hairs on the crown have the more primitive cranio-caudad trend with no suggestion of the frontal whorl seen in the Entelloids. These hairs moreover are somewhat upstanding, becoming more closely applied to the head posteriorly, where they pass into the main cranio-caudad tract of the mid-dorsal region. This tract is continued on to the tail. On the sides of this median tract the hairs have a very distinct lateral tendency, and on the lower part of the flanks they are decidedly outstanding from the body. The short hairs around the mouth have a direction towards the margins of the corresponding lip. On the chin and throat they stand out from the surface, but are directed mainly forwards. The longer hairs forming the whiskers spring from the pre-auricular region and pass directly outwards, or outwards and upwards. The upper ones are longest and conceal the ears in front view partially or completely according to race. They are longer in the male than in the female, and in the former they may have a downward twist at their extremities. In the female they turn forwards at the tip and the countenance thus has a more rounded contour.

On the chest the hairy coat is less evident, and the individual hairs have no particular direction, but towards the lower chest the main trend is cranio-caudad. A similar trend is exhibited by the hairs on the mid-ventral line of the abdomen. But on the lateral parts of the abdomen there is a definite reversal commencing below in the inguinal region and sweeping upwards and laterally to meet the hairs coming down on the flanks from the dorsum. In this way a prominent shelf of outstanding hairs is formed on the lower flank. This no doubt serves as a means of throwing off rain. It may be noted that when the animal scratches its abdomen it does so in the direction of this inguinal reversal.

In the axilla, hair is scanty and arranged as in Man in a radiating fashion from the centre of the space. Over the deltoid and on the brachium the hair is denser and has a trend posteriorly and distally towards the posterior margin of the limb. This general trend is continued on the forearm, wrist, and dorsum of hand and fingers, except that on the radial border of the forearm and wrist the drift is directly distal, whilst towards the postaxial side on the upper third there is a distinct tendency to an elbow convergence.
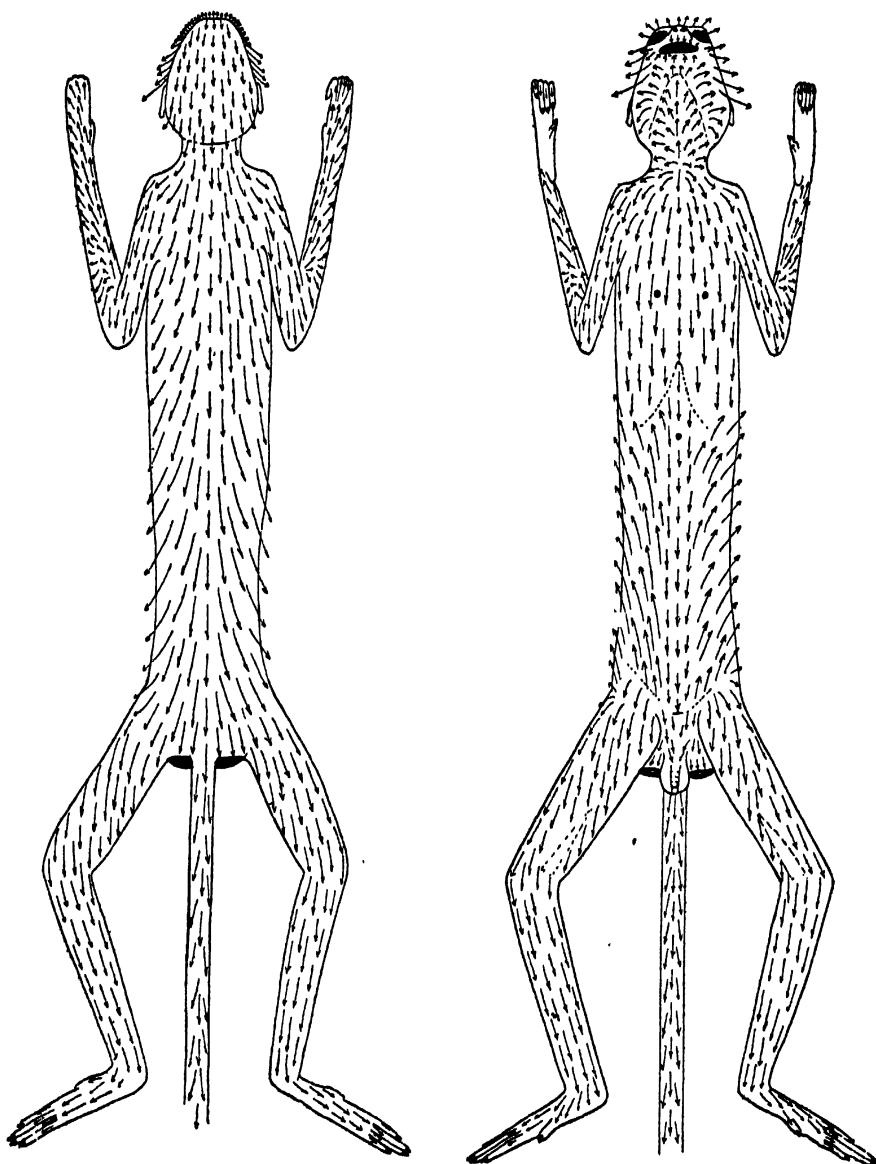
Fig. 1. Hair-tracts of *Pithecus vetulus*

a dorsal aspect   *b* ventral aspect

On the lateral aspect of the buttock the hair is shortish and has a trend towards the adjacent margin of the callosity. On the thigh there is a similar trend towards the posterior margin of the thigh, with an additional tendency to point upwards towards the callosity at the upper third. On the anterior part of the thigh, especially on the flexor side, the trend is directly distal. On the crural region the hairs are also directed distally, and this trend is continued on the ankle and dorsum of the foot and toes. Here, however, the hairs are longer than on the corresponding parts of the hand, so that they overlap more at the margins.

3. Skin pigmentation (Text Fig. 2)

Pithecus vetulus is remarkable for the extent of the distribution of melanin pigment in its skin. A full study can only be made by completely shaving off the hairy coat from the animal,—a method of study which does not appear to have been adopted hitherto in scientific mammalogy. The account given below is based mainly on specimens of *P.v.vetulus* and *P.v.nestor*. Other races depart in certain respects from this description.

The naked part of the face is a characteristic deep purplish-black with a glossy surface. This is in great contrast with the dull sooty black of the Entelloids. But this dark pigment is not confined to the face. It extends upwards on to the scalp and laterally on to the cheeks, so that practically the whole of the head, including the ears has a bluish-black coloration. On the dorsal surface (Fig. 2) pigment usually ceases on the nape and there is no more until the lower lumbar or sacral region is reached. Here a triangular patch develops over the area covered by the shorter hairs mentioned earlier on. From thence the pigment extends on to the tail, which is wholly black, and also on to the buttocks and extensor aspects of the thighs, which are also quite black. On the ventral surface (Fig. 2), on the other hand, heavy pigmentation occurs on the throat and chest, usually as far out as the anterior or mid-axillary line. It is paler on the throat than on the face. It is very dark on the mammary areola. Pigment also occurs on the belly and groins and is continued on to the genitals, perineum and callosities and flexor aspects of the thighs. Although the scrotum and prepuce are pigmented, the glans penis is not. The same relates to all the parts of the female, except the clitoris.

On the upper limb pigment passes from the pectoral region on to the anterior part of the deltoid region, and thence on to the extensor surface of the brachium and forearm. Thence pigment proceeds on to
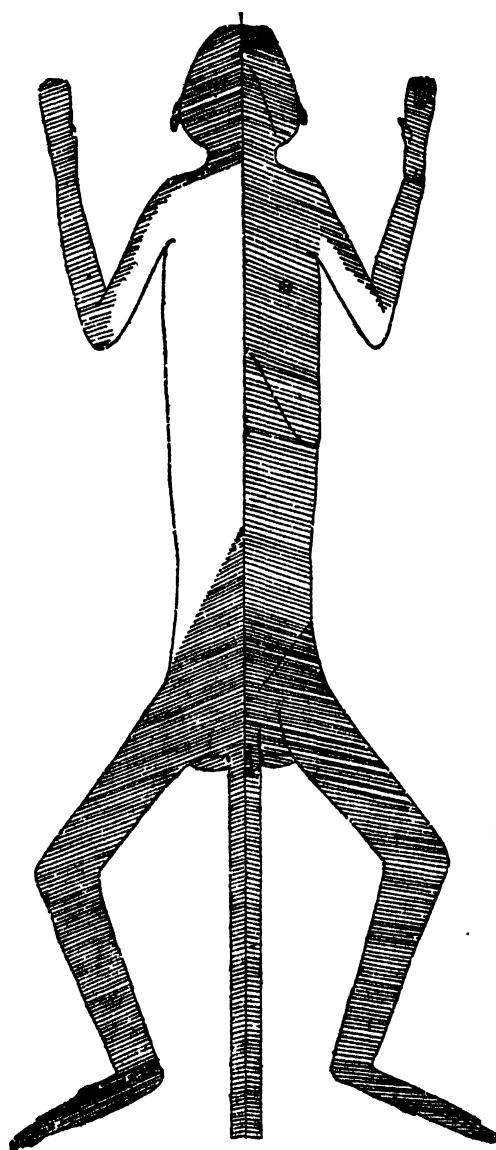
Fig. 2. Diagram to show the distribution of skin-pigment in the
adult *Pithecus vetulus*

On the left half of the diagram the dorsal distribution is represented; on the right half the
ventral distribution. Pr portions drawn to scale.

the dorsum of the hand. The flexor surface of the brachium and forearm are generally unpigmented. The palm and fingers are very heavily laden with pigment.

The lower limb is pigmented throughout, the naked parts of the feet being very heavily laden. Nails are black on both fingers and toes.

It must be pointed out that the above account of the distribution of skin-pigment in *P.vetulus* is applicable only to the adult. In the new-born, pigment is absent or poorly developed. The face is white at first and then develops a pallid lilac hue. The ears are only slightly dusky, and the palms and soles somewhat darker. Body pigmentation had not yet commenced in the youngest individual examined. In a male *nestor* about one-third grown the face, ears and naked parts of the limbs had developed the full pigmentation, but the scalp, dorsal surface of the body, proximal two-thirds of the tail and most of the upper limbs were unpigmented. There was a commencing blackening of the ventral parts and of the hind-limbs.

4. Albinism

At this juncture it will be convenient to discuss the question of albinism in relation to these monkeys, before passing on to the consideration of special regions.

As albinism is so common in the animals of Ceylon, it is not surprising that the condition frequently occurs in the monkeys of this species. As a general rule albinism in Primates is rare. Even in the Primates of Ceylon the condition in its fully developed form, *i.e.*, with complete absence of melanin pigment from skin and hair and also from the iris, is common only in Man. It has recently been reported in the Macaque (*Macaca sinica*) by the present author (1933), but has not yet been observed in this complete form in any of the Leaf-monkeys, unless we accept Knox description of white monkeys to mean complete albinos of the present species. No degree of albinism has been observed in the Ceylonese representative of the Entelloids (*P.entellus thersites*). In *P.vetulus*, on the other hand, albinism is comparatively common, but only in a partial form. Moreover, examples have now been recorded from many parts of the known range of the Purple-faced Monkeys in Ceylon, so that it is probable that all the Ceylonese races of this species are liable to the condition in a partial form, with the possible exception of the Bear Monkey. I am unaware of any instance of albinism in the Malabar race of this species. ·

It has already been shown (p. 26) that the earliest Leaf-monkeys recorded from Ceylon were white specimens,—probably partial albinos

of one of the lowland subspecies of *P.vetulus*. The first mention of them was by Robert Knox (1681) who described them as white in face as well as body. Then came Ray's account (1693) of a white Ceylonese monkey in which only the body was white. This formed the basis of Linnaeus's name *Simia veter*, which thus came to be regarded as a different species of monkey from the black Ceylonese monkey also described by Ray. The same ' species ' was represented by Erxleben's name *senex*, which was based on Knox's description. By this name the White Wanderoo was known to most of the naturalists of the nineteenth century. Many, including Anderson and Blanford, felt that the animal was probably only a variety of the ordinary Purple-faced Monkey, though still treating it as a separate species. They seem to have been influenced by the statements of many observers who maintained that these white animals were always found in troops apart from other monkeys. Forbes (1895) definitely placed *senex* as a variety of *cephalopterus* (*i.e.*, *vetulus*). Blanford examined a specimen of this kind in the Leyden Museum. This was the one chosen by Schlegel to serve as a type for Erxleben's *senex*. Pocock (1928 *a*) seems to have been still uncertain about the status of these white animals, and, choosing the name *senex* as the specific name for all the Purple-faced Monkeys, he restricted the typical subspecies to the albinistic forms, largely because he felt that this type of monkey was a hill race, on account of the fact that Kelaart (1852) had described a white specimen from Matale under the name *Presbytis albinus*. Meanwhile, however, Phillips (1926 and 1927) had clearly shown that all the normally coloured races of *vetulus* were liable to partial albinism, and that examples had been recorded from nearly all the parts of the known range of *P.vetulus*. Others have been recorded or seen since that date. The different white specimens that have been described from time to time therefore differ among themselves in the same way as their normally coloured counterparts do, besides differing in the degree of albinism. It is furthermore established that the statements of the older field naturalists regarding the constitution of white colonies of these monkeys were not correct. White specimens are often seen in company, as was mentioned by Knox and Tennent in the hills, and as may still be seen to-day for instance at Baddegama in the Southern Province and again in the East Matale District. This is because the condition is hereditary and, once occurring within a troop, the offspring of that troop will frequently themselves be albinistic, until, in some instances, a whole troop may consist of albinos. More usually, however, two or three white individuals are seen in company with normally coloured animals. The various specimens of white monkeys that have

from time to time been described are therefore to be regarded merely as albinistic individuals of one or other of the four Ceylonese races of *P.vetulus*. The earliest specimen, *e.g.*, Ray's and the one obtained by Temminck and utilized by Schlegel as the type of Erxleben's *senex* were probably lowland forms, *i.e.*, albinos of either *vetulus vetulus* or of *v.nestor*. Knox's animals were possibly albino Bear Monkeys or albinos of an intermediate form between the Bear Monkey and *P.v.nestor* and now extinct. The Dambulla troop mentioned by Spence Hardy (1853) and Tennent (1861) was probably referable to *P.v.philbricki* (q. v.).

Although these albinos differ among themselves in the degree of pigmentary lack, there is a relatively common standard from which departures are only of minor degree. In this standard type the pigment is present on the face and ears as in normal animals. The brown cap is also nearly always in evidence. The hands and feet are frequently mottled—partly pigmented and partly flesh-coloured—but they may lack pigment altogether. Callosities are generally black. The body hair and the hair on the limbs is mostly white,—a dirty yellowish-white. This also occurs on the tail. But there may be on the upper back and flanks large irregular patches in which there is some black pigment. The hair on the distal parts of the limbs may also bear some pigment, giving a brownish or blue-grey tinge to these parts. A typical example is depicted in Plate VII.

I have examined the specimen of ' *Semnopithecus senex* ' in the Calcutta Museum. This is a young animal not more than half-grown, and was sent to Calcutta by Keluart in 1851. It is probably the one on which he based his description of *Presbytis albinus*, though this is not stated on the label. It is impossible to state definitely to what race it belongs, as it is so faded and worn. The general colour is a dirty yellowish-white, but the brown cap is present, and there is a fair amount of grey on the back, especially on the shoulders,—though not so much as in the living specimen depicted in Plate VII. The limbs appear to have been wholly white. The specimen is too old to make any accurate statements regarding pigmentation of the skin. The hair is fairly long and woolly, so that it quite probably belonged to *P.v.monticola* or to a hill form of *philbricki*. Keluart's *albinus* was obtained in the Matale district which is within the territory of *philbricki*.

5. Characters of the face (Text Fig. 3)

The nature and colour of the facial skin have already been mentioned. The face as a whole is, for a Catarrhine Monkey, very flat,

there being the minimum of muzzle prominence in the adult and none at all in the young animal.

Fig. 3. Drawing of the facial characters of *Pithecus vetulus nestor*, adult male.

The surface of the adult face is everywhere smooth, except for some small tubercles on the lips at the sites of attachment of some short rudimentary sinus hairs. In the new-born the face is curiously wrinkled, and on the upper lip there are some grooves with intervening convolutions running at right angles to the lip margin. These gradually fade out during adolescence. The lips are thin, and meet edge to edge, with no pouting. They are not as protrusible as those of the Anthropoid Apes. Pigment extends to the free margin of the lip, and for a millimetre or so on the mucous surface of the lip. There is often a little bluish pigment on the fore part of the gums also.

The cheek bones stand out in bold relief, but immediately below these the cheeks are hidden by the profuse growth of the whiskers. These grow laterally and conceal the lower half of the ears, and in some races more. Above the whiskers there are some scattered black hairs over the cheek bones. These are continuous above with the lateral extensions of the black brow-bristles. A linear tract of black hairs may extend backwards along the upper edge of the whiskers as far as the ear. They thus serve to separate the whiskers

from the brown pileum. In the Bear Monkey they are much more heavily developed and form a sharply defined triangular black area in this position.

The eyes are large, especially in the young, and are placed fairly close together. The eyelids are clothed with very thin, mobile skin, and their margins are provided with short lashes both above and below. The eyelashes are longer and more numerous on the upper lid than the lower, being very scanty on the latter. The palpebral fissure measures 13 mm. in length. There is a lacus lachrymalis and a short membrana nictitans, both deeply pigmented. The conjunctiva is unpigmented except for a very narrow tract near the margin of the eyelids. The irides are bright hazel-brown in colour, and the pupil circular.

The external nose is depressed and broad. For a Catarrhine Monkey the septum is very broad, especially in its upper half. The nares, however, are directed forwards. They are reniform in outline, with the concavity medially. The lower end is nearer to the mid-line than the upper. In length the nares measured 9 mm. in a large male *P.v.nestor*, but in width their maximum was only 4.5 mm.

The ears in *P.vetulus* resemble those in *P.obscurus* very closely and thus differ considerably from those of *P.entellus*. In general the organ may be described as a small flattish ear not standing out prominently from the head. It is partially or wholly concealed by the whiskers. In outline it is rounded, showing no trace of the point so characteristic of the Entelloid ear; it is, however, more elongated

a   b   c
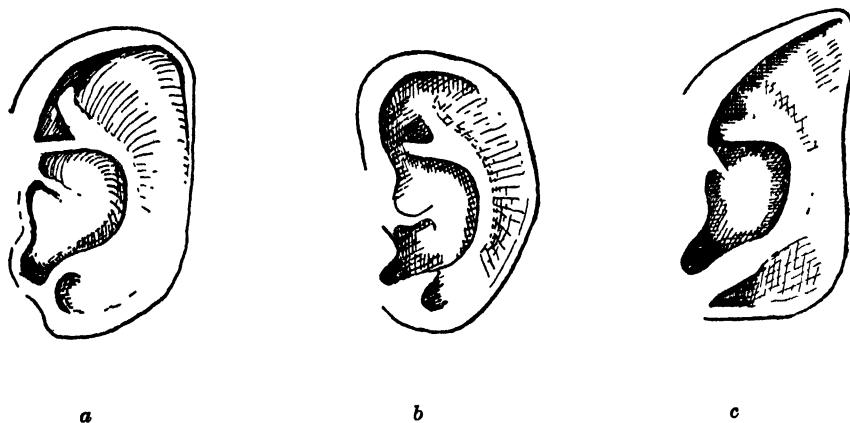
Fig. 4. Drawings of the external ear in *a Pithecus vetulus nestor*, *b P.obscurus*, and *c P.entellus thersites*

from above down than the ear of *P.obscurus*. The lateral
aspect is sculptured into ridges and fossae on a complicated plan.
There is a well marked helix extending well round on to the posterior
margin and springing anteriorly by two roots. The antihelix is similar
to that of Man, springing from two broad roots separated by a trian-
gular fossa. There is an antitragus, a definite intertragic notch, and
a low tragus anteriorly. Below the antitragus the ear is sculptured
into a depression with a raised anterior margin, corresponding to the
bursa of lower forms. There is a distinct suggestion of that—other-
wise exclusively human attribute,—the lobule.

The ear early reaches its full size during growth, being relatively
larger in the young than in the adult.

6. Perineal Region (Fig. 5, a and b)

The anus is a small puckered opening situated some distance ventral
to the base of the tail within a large area of bare, but pigmented
skin. The skin of this area is not absolutely naked, but has a few
very short hairs upon it. The bare area extends as a triangular field
on to the ventral aspect of the tail for an inch or more. Within the
same bare area are situated the two ischial callosities. These are
moderate in size, but rather variable in shape. In the male the
common shape seems to be ovoid, with the broader end laterally and
the narrow end medially and somewhat below, so that the long axis
of the structure runs obliquely. The obliquity, however, is very vari-
able. In some specimens, especially females, the outline is more
triangular. The callosities are surrounded and separated by a very
narrow zone of almost naked skin continuous with the bare skin
already mentioned around the anus. The callosities are black in
colour. *P.vetulus* differs from the Entelloids in the obliquity of the
long axis of the callosities and from *P.obscurus* in the pigmentation
of the bare area of the perineum.

7. Male Genitalia (Fig. 5, a and c)

The external genitalia are small as in most Leaf-monkeys. The
scrotum is small and pigmented, and situated relatively far back.
Its skin is smooth and almost hairless. The penis varies consider-
ably in size and is singularly human in appearance. It is provided
with a long, loose foreskin which is not attached by a fraenum as in
Man, thus being capable of being withdrawn for a considerable dis-
tance. It is pigmented and shows some annular foldings. The glans
is hemispherical, smooth, and unpigmented. It is usually unclothed

by the foreskin. The external urinary meatus is a vertical slit without raised lips, situated a little below the tip of the glans. The corona glandis is entire, and sharply marks off the glans from the body of the penis, a portion of which can be freely exposed as a cylindrical object by withdrawing the foreskin. The penis of the Entelloids has the same general plan, but the glans is shaped differently, and its corona is notched. The external urinary meatus moreover, has raised lips.

8. Female Genitalia (Fig. 5, b)

The vulva is small and situated very far back, lying between the callosities in their upper (dorsal) half. Contrary to the statement made by Pocock (1926), who examined an immature individual of *P.vetulus*, the vulva is dorso-ventrally elongated as in most monkeys.
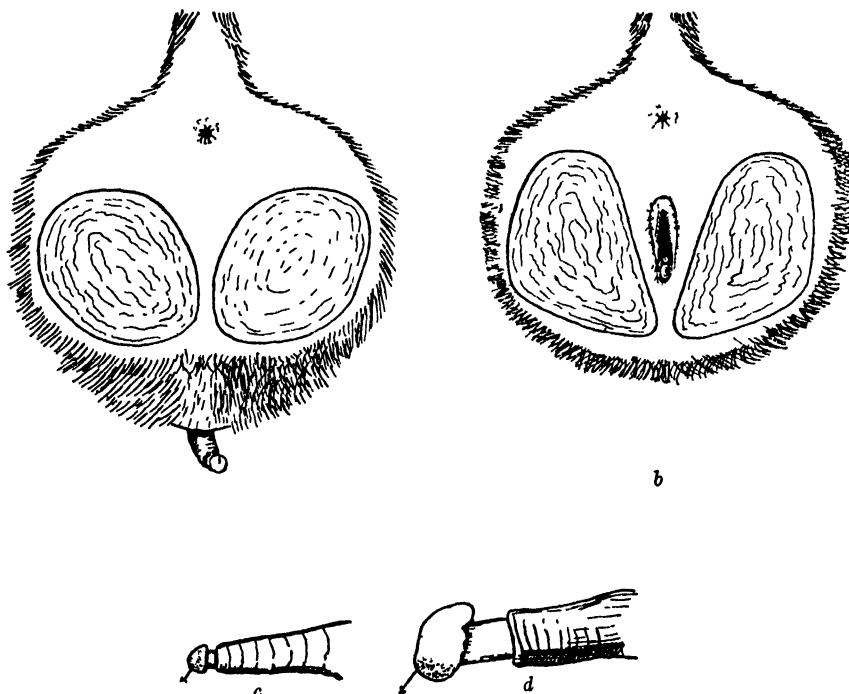
Fig. 5. Perineum and genitalia in *Pithecus vetulus*

a, Perineum of the male; *b*, ditto of the female; *c*, side view of the penis of an adult male; *d*, same of adult male *P. entellus thersites*

It measures 9-10 mm. from commissure to commissure, but only 5 mm. across at its widest part, which is opposite the vaginal opening. The lips are barely worthy of the name. They are but little raised from the surrounding skin, and their inner aspects lead directly into the vaginal lumen. They are best developed around the vagina, where the skin may be puckered and pouting. Anteriorly they are thin and unite in a pointed anterior (i.e., ventral) commissure. The posterior (or dorsal) commissure is more rounded. They are covered by a few whitish hairs.

Contrary again to Pocock's statement, and thus agreeing with Sonntag's (1924) observations, the clitoris is relatively large, and prominent, and is not normally concealed by the labia even in the living animal. This organ is unpigmented like the rest of the vulva. It is firm, arched and not surrounded by a prepuce. Its body is cylindrical, but grooved on its concave aspect. The glans is shaped as in the glans penis of the male, but is notched below. There is no fraenum, and its surface is delicately papillated.

Other than a slight amount of bleeding, there are no external changes to be observed during the period of menstruation.

A characteristic feature of the female is a triangular patch of white or yellowish-white hair on the pubic region below the callosities. The base of this triangle is situated medially on the lower part of the pubic symphysis. The apex extends some distance laterally on to the postaxial part of the medial surface of the thigh.

The nipples are small when lactation is not taking place. During pregnancy and lactation they elongate to form dependant subcylindrical structures 15 mm. long. They are, with the surrounding areola, very darkly pigmented. They lie opposite the third rib about 20 mm. from the mid-line.

9. Hand and Foot (Fig. 6, a and b)

In the great elongation of the hand and foot and in the rudimentary condition of the pollex, *P.vetulus* agrees with all the members of its genus, and also with the *Colobi* of tropical Africa. The elongation, however, is not so extreme in the Purple-faced Monkeys as in the Entelloids, but there is little difference between them and *P.obscurus* in this respect. On the dorsum the fingers and toes are haired as far as the penultimate phalanx and the hairs are long enough to overlap the margins of the digits. The nails are in all cases elongated beyond the tip of the digits and are markedly convex from side to side. They are pigmented. The fingers and toes are webbed as far as the first interphalangeal joints of all the digits, the web in each case being composed of lax skin and presenting a concave margin

distally. The general characters of the naked parts of the palm and sole can be made out from the diagrams in Fig. 6 below. On the hand the prominent heel-like projection of the naked part proximally at the ulnar side is noteworthy. The arrangement of the flexure lines and of the complicated papillary ridges can all be gathered from the drawings, making further description unnecessary.
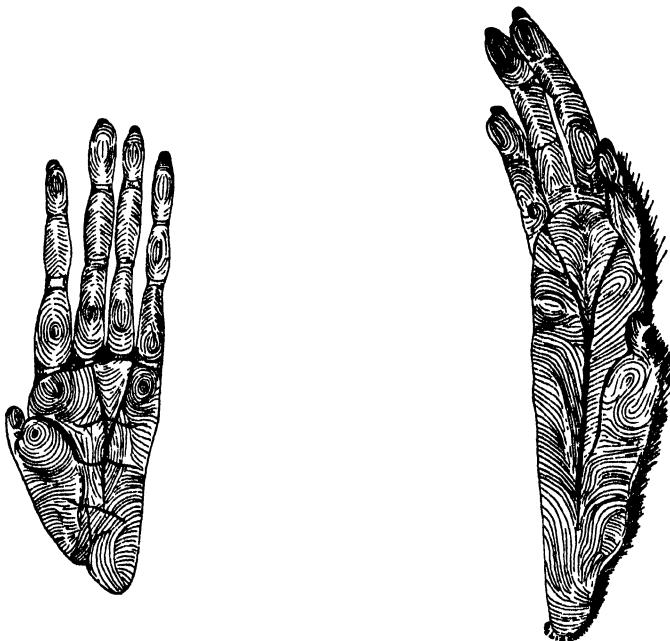
Fig. 6. Drawings of left hand and right foot of an adult
Pithecus vetulus philbricki × ½

THE SKULL [1] (Plate IV)

Although differing considerably in size in the different subspecies, the skull is always small relative to the trunk and limbs. It is further invariably a rounded or ovoid object, for its surface is not marked by outstanding ridges and processes such as occur in the skulls of

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[1] Based on the examination of 39 skulls of *P. vetulus* compared with 10 skulls of *P. entellus*.

Entelloids. In this respect, as well as in many others, the skull of *P.vetulus* approaches more closely to that of the *pyrrhus* group than to any others.

Beyond this broad statement it is difficult to speak very definitely, for, as Pocock (1928 *a*) remarked, there are so many variations to be met with in any large series of skulls of *P.vetulus*. The variations do not seem to be connected constantly with race, sex or age, but to be of a purely individual character.

The cranium is ovoid or subglobular, somewhat compressed dorso-ventrally, and flattened on the base. In the main it is smooth. The temporal lines are poorly developed, and only in old males of the larger races do they form outstanding shelves, and even then but poor ones. Posteriorly the two lines recede from one another. They do not approach the vertex very closely, but come nearer thereto in the Bear Monkey than in the other races. The occipital crest is also feeble, and like the temporal lines does not as a rule form a shelf as it does in the Entelloids. It consists of two slightly arched halves united in a small downwardly projecting tubercle at the inion. Laterally the two halves run toward the mastoid region, and are separated from the posterior root of the zygoma by a triangular smooth area of varying size.

The surface of the cranium is marked by sutures only in the juvenile and adolescent skull. The coronal suture extends well back in the mid-line as far as or beyond the vertex. Laterally it passes forwards rapidly towards the pterion. The metopic suture disappears very early indeed. The sagittal suture is relatively straight and persists longest. The lambdoid suture forms a gentle arch meeting the occipital crest at the same point as the temporal lines in each side. In *P.entellus* the lambdoid suture is straight in the middle and dips down sharply at the two ends. The frontal bone is swollen in the middle, but constricted laterally. The parietals are flattened near the sagittal suture, but bulging at the sides, giving a globular outline to the cranium when viewed from above. Below the crest the occipital bone is flat, sloping down towards the opisthion at an angle of about 55 degrees to the basis cranii. The squamous temporal continues the bulge of the lateral part of the parietals and thus encroaches somewhat on the temporal fossa. The pterion is formed in most instances by the meeting of the alisphenoid with the anterior inferior angle of the parietal, but there are many variations in this region. The temporal fossa is further encroached on by the bulging of the lateral wall of the orbit,—a point which further distinguishes the skull from that of the Entelloids. The outer wall of

the fossa formed by the zygoma does not project far from the side wall of the cranium, and the arch itself is much weaker and more slender than in the skull of *P.entellus*. The fossa is therefore less roomy in every way in this species, a fact correlated with the smaller size of the temporal and other masticating muscles and thence with the poor development of the bony buttresses, *e.g.*, supraciliary ridges, which withstand the stresses due to this group of muscles. The coronoid process of the mandible occupies the fossa midway between the lateral wall of the cranium and the zygoma.

On the basis cranii the mastoids call for remark. These are variable in development, but in some specimens they form distinct prominences. In all cases, however, this region is excavated by air cells, and these extend backwards in the diploe as far as the occipital crests and medially to the temporo-occipital junction. The petrous temporal is also excavated to some extent. The foramen magnum is usually wider transversely than antero-posteriorly, but this opening is very variable in shape. The long axes of the occipital condyles lie nearer to the transverse than to the sagittal plane. The basi-occipital and basisphenoid bones remain distinct until adult life. Together they are long and narrow, but not so much as in *P.entellus*. The rest of the base is not different from that in other Leaf-monkeys.

On the face the most striking fact is the almost complete absence of supraciliary ridges. At most these slope gradually from the surface of the frontal bone, and there is no clear gutter between these two structures as in most monkeys, including the Entelloids. They are best developed in the larger forms, more particularly in *P.v.philbricki*. The orbital margin is almost a perfect circle, but its perfection is encroached upon at the lower medial angle. There is no supraorbital foramen or notch. The plane of the orbital margin slopes downwards and forwards. Immediately within the orbital opening the orbit is dilated into a globular anterior portion. This encroaches on the cranial cavity above, on the maxillary antrum below and on the temporal fossa laterally. The septum between the two orbits is very narrow, being thickest on the surface, but rapidly thinning behind. In *P.entellus* it is thin at the back, but thickens gradually anteriorly. The lachrymal foramen is variable in both types. The sutures on the orbital walls disappear rather early. The sphenoidal fissure is reduced almost to a foramen lying below and lateral to the optic foramen. It is relatively larger in *P.entellus*. The orbit is relatively larger in the juvenile skull than in the adult.

The nasal aperture is very variable in form in *vetulus* and in the Entelloids, though on the average the aperture is shorter and broader

in *vetulus* than in *entellus*. It is pyriform in shape with the pointed end situated near the alveolar margin, and sometimes approaching it very closely, or at any rate connected with it by a groove. The groove is less marked in *entellus* even if present.

The nasal bones rapidly lose their identity during adolescence, but in the young skull they are triangular and very narrow from side to side. They fuse together before fusing with the nasal processes of the maxillae and premaxillae. The premaxillae can only be seen in young skulls, but their outlines persist in some specimens till near adult life. They ascend as far up as the lower half of the nasal bone. The maxillae call for no further remark except that the infraorbital foramen is double or multiple.

The palate is relatively shorter and wider than in the Entelloids, a fact coupled with the lesser degree of prognathism in the present species. The lateral tooth rows in the upper jaw are bowed outwards, whereas in the adult of *P.entellus* they are practically straight. The anterior palatine canals are very variable but on the whole may be said to be smaller and more rounded in *vetulus* and longer and narrower in *entellus*. The posterior palatine canals were said by Anderson to differ in the two species. Again there are numerous individual variations in both species, so that similar types of canal are to be seen in both, but, on the average, they tend to be closer together in *vetulus* on account of the bowing inwards of the tooth row. They are also oblique in position, being elongated anteroposteriorly, and passing into a groove on the hard palate. In *entellus* they are more rounded in outline and do not show the groove in most cases.

The mandible differs from that of the Entelloids in several points. The chin is less receding in *vetulus*. The rami are more strongly built in *entellus*. The horizontal ramus is relatively shorter in *vetulus*, whilst the sigmoid notch is narrower and deeper. As already mentioned the relative bigonial measurement is greater in *vetulus*.

Summing up then, the skull of *vetulus* as compared with that of the Entelloids may be described as a smaller, more rounded object. In most of its measurements it tends to be shorter and broader, and this affects the face more particularly. It is moreover, a less strongly-built skull. The masticatory apparatus is less well-endowed and therefore the jaws and supraciliary ridges and the markings for the temporal, pterygoid and masseter muscles are less obvious and of less extent. The whole face is flatter, due to the lesser tendency to prognathism.

GEOGRAPHICAL DISTRIBUTION (see Map, Plate IX)

Pithecus vetulus is confined to Ceylon and South India. In India
.a single race is restricted to the wet, western Malabar tract, which
extends from Cape Comorin in the south, northwards, including Coorg,
as far as the Tapti river. This area includes the Western Ghâts, and
the Nilgiri, Anamalai, and Palni hills. In Ceylon the species is also
mainly restricted to the wetter districts, *i.e.*, the western and south-
western lowlands and the central hill ranges; but from the East Matale
Hills its range extends northwards into the drier lowlands around
.Sigiriya, Minneriya, and Kantalai to Trincomalee and Horowapotana.
It also descends the mountains on their eastern slope into the valley of
the Mahaveli-ganga in its northward course. This river probably
separates it from the territory of the Entelloids in this part of its course.

P.vetulus is absent in Ceylon from the western lowlands north of
·Colombo. It is believed to occur in the Kurunegalla district, or just
·south of it, but not to the north. If a line is drawn across the Island
from the mouth of the Kelani-ganga on the west to that of the Yan-oya
on the east, no specimens of Purple-faced Monkey will be found north
of it. On the south-east the territory of *P.vetulus* meets that of the
Entelloids in the lowland area at about Ranna, mid-way between
Hambantota and Tangalle.

GEOLOGICAL CONSIDERATIONS

Although no definite remains belonging to the present species have
·been discovered it is possible through analogy with other animals to
reconstruct its probable migrations in the past. In the first place it
is to be remembered that the nearest ally of *P.vetulus* is considered to
be *P.obscurus* of Malaya. The species therefore agrees in its distribu-
tion with quite a number of other Ceylonese forms, *e.g.*, the Lorises
and many birds such as *Phoenicophaes* (see Wait, 1914) which are
·confined to Ceylon and to the Malabar tract, and whose nearest existing
relations are to be found in the Himalayas, in Malaya or in Africa or
in all of these places.

As regards the Primates, the theory is well-established that in Miocene
and Pliocene times there was a dispersal centre situated in the Siwalik
Hills at the foot of the western Himalayas in the Punjab. Here have
been found remains of Anthropoid Apes (*Dryopithecus* and *Palaeopi-
thecus*) and of Leaf-monkeys similar to those existing to-day (named
Semnopithecus palaeindicus by Lydekker in 1886). It is probable
that the migrations of the Leaf-monkeys have been similar to those

of the Anthropoid Apes and the Lorises. In the case of the Apes it
is considered probable that *Dryopithecus* migrated westwards into
Europe, and it is to be assumed that a branch of this migration spread
into Africa and developed in its tropical zone into the Gorillas and
Chimpanzees. An eastern migration gave rise to the Gibbons and
Orangs. Similarly with the Lorisoids, there are European represen-
tatives (*e.g.*, the extinct *Pronycticebus*, *Pseudoloris*, &c., see Weigelt,
1933) and the existing African Pottos and Galagos on the one hand,
and the Oriental Slender Lorises (*Loris*) and Slow Lorises (*Nycticebus*)
on the other.

In exactly the same way Africa has received a branch of the Leaf-
monkey phylum in the shape of the *Colobus* monkeys, whilst the Indo-
Malayan drift gave rise to the true *Pithecus* monkeys and the more
aberrant forms like *Nasalis*, &c. As far as *Pitheci* are concerned there
are evidences of two distinct waves of migration from the Siwalik
dispersal centre southwards into India and Ceylon and also south-
eastwards into Malaya. During the interval between these two waves
Ceylon was separated from the mainland and reunited again.

Geological evidence supports the view that Ceylon has been united
to South India on at least two occasions during the Tertiary era. One
was probably during the time when more northern latitudes were in
the throes of the Ice Age. The other occurred much later, probably
as recently as the historic period, but at any rate since the advent of
Man on the globe (see Wait, 1933).

On these grounds it is submitted that the Slender Lorises (*Loris*)
and the Purple-faced Monkeys (*Pithecus vetulus*) are relics of the
original fauna left in Ceylon after most of the animals had drifted back
again on the retreat of the Ice barrier in more northerly parts during
late Pleistocene times. This fauna had originally come to South India
and Ceylon by virtue of the *vis a tergo* of the uncongenial glacial con-
ditions in the Himalayas, more particularly from the Siwalik area
where the climate had been hitherto equable. A more easterly drift at
the same period gave rise to the *pyrrhus* group of Leaf-monkeys in
Malaya. The Purple-faced Monkeys left stranded in Ceylon after the
isolation of the latter proceeded to evolve into the different forms
recognized to-day, whilst the Malabar relic went even further and
became specialized so as to be worthy almost of distinct specific rank.

With the reunion of Ceylon to India in later times a fresh southern
influx of animals occurred. Not all animals in this second migration
succeeded in getting over Adam's bridge, and not all that were suc-
cessful went so far as to colonize the whole of Ceylon. The Tiger
reached Cape Comorin, but was unable to reach Ceylon. Among those

that crossed and colonized the drier part of Ceylon was a new type of Leaf-monkey,—the Entelloid. Despite the wide distribution of this form in Ceylon, in only one district,—the north-east,—does it mingle with the members of the older migration. This last migration of Leaf-monkeys was so recent that there has been no time for the Ceylonese animals to evolve a form in any great degree different from those living on the mainland opposite, although Pocock (1931) has recently separated the Ceylonese form as *P. entellus thersites* and later (1931) admits that *thersites* exists also in the extreme south of India, with the other form, *pallipes*, living further north. It is important to note that the animals that appeared in Ceylon during this second wave of migration have their nearest mainland counterparts in the dry Carnatic region, and not in the Malabar region as with the older forms. It follows therefore that the Purple-faced Leaf-monkeys and the *pyrrhus* group of Leaf-monkeys should be regarded as more archaic and generalized than the more recent and more specialized Entelloids of the second migration.

If the above hypothesis of the wanderings of the Indo-Ceylonese and Malayan Leaf-monkeys is accepted, it will be gathered that it is quite unnecessary to postulate the existence of the continent of Gondwana-land (or ' Lemuria ' of Sclater) connecting Madagascar, through Ceylon, with Malaya, at any rate after the close of Jurassic times. The peculiar distribution of the Lorises was at one time held as a big argument in favour of the existence of such a land connexion in Tertiary times; but it must be noted that the nearest relatives of the Lorises are not the Madagascan Lemuroids but the tropical Ethiopian Pottos and Galagos. The Madagascar forms must have been separated from the more generalized Lorisoids for a considerable period, during which time they have undergone a wild riot of specializations. More-over, the depth of the oceans around Ceylon, except in the Gulf of Mannar, is such that it is very unlikely that such a vast subsidence has occurred so recently as would be required to account for the migration of Leaf-monkeys between Ceylon and Malaya or of Lorisoids from Madagascar to Ceylon.

PART. II—SYSTEMATIC

1. Pithecus vetulus vetulus (Erxleben)

The South-western Purple-faced Leaf-monkey or Black Wanderoo

Purple-faced Monkey	1793 Pennant, *Hist. Quadr.*, I, p. 199
	1800 Shaw, *Gen. Zool.*, I, pt. 1, Pl. XIII
Cercopithecus vetulus	1777 Erxleben, *Syst. Reg. An.*, p. 25
C.kephalopterus	1780 Zimmermann, *Geogr. Ges.*, II, p. 185
Simia cephaloptera	1785 Bodd., *Elench. An.*, p. 65
C.silenus purpuratus	1792 Kerr, *An. Kingdom*, p. 65 et al
Simia porphyrops	1795 Link, *Beitr.*, II, p. 62
S.latibarbata	1807 Temminck, *Cat. Syst. Ornith. et Quadr.*, p. 3
C.latibarbatus	1812 E. Geoffroy, *Ann. du Mus.*, XIX, p. 94
C.leucoprymnus	1825 Otto, *Nova Acta Acad. Nat. Cur.*, XII, p. 505
	1827 Lesson, *Man. de Mammif.*, p. 37
Semnopithecus leucoprymnus	1827 Desmarest, *Dict. des Sc. Nat.*, XLVIII, p. 439 et al
S.cephalopterus	1841 Martin, *Nat. Hist. Quadr.*, p. 482 et al
Presbytis cephalopterus	1843 Gray, *Handlist Mamm. (B. M.)* p. 4 et al
Pygathrix (Presbypithecus) ceph-	
aloptera	1913 Elliot, *Rev. of the Primates*, III, p. 68
Pithecus kephalopterus	1918 Wroughton, *J. Bombay Nat. Hist. Soc.* p. 560
P.veter	1918 Wroughton, *loc. cit.*, XXV, p. 561
P.vetulus vetulus	1923 Hinton, *Ann. Mag. Nat. Hist.* (9), XI, p. 509
	1926 Phillips, *Ceylon J. of Sci.* (B), XIII, p. 273
P.senex vetulus	1928 Pocock, *J. Bombay Nat. Hist. Soc.*, XXXII, p. 501

Sinhalese : *kalu vandhura*
Tamil : *mundi*

The typical race of *P.vetulus* is defined as the medium-sized black form inhabiting the wet south-western lowland area of Ceylon to the south of the Kalu-ganga.

Type. No type is known for this race. It was originally described by Ray in 1693 from a specimen in the Leyden Museum, and the locality merely given as ' Ceylon '. The description, however, is sufficient, taken in conjunction with the one given later by Erxleben, to warrant the name *vetulus* being applied to the form defined above. At that time Galle was the chief port of Ceylon, so that monkeys brought from the Island would most likely be from the district near to that port. This district may therefore with safety be considered the type-locality.

Material examined. The account given below is based mainly on a series of eight specimens of varying ages shot at Hiyere, near Galle, in September, 1931, and preserved at once by formalin injection. A large series of skins in the Colombo Museum from various districts has been examined for comparison.

External characters: adult male. Various descriptions of the coat-colour are to be found in the literature, but most are based on faded material. This applies in particular to the account given by Elliot.

General colour of body and limbs jet-black; hairs slightly frosted with white in the mid-dorsal region. Pileum sepia-brown in front, but paler posteriorly and on the nape. Brow-hairs black and extending backwards towards the ears as a linear black tract only. Lower lumbar and sacral regions clothed with a triangular silvery-white patch sharply defined from the surrounding black areas. The apex of this patch is six inches above the base of the tail. Laterally it extends for some distance on to the lateral aspect of the thigh, as far down as the knee in some individuals. It also extends for some two to three inches along the dorsal aspect of the tail. Remainder of tail mole grey becoming reddish-brown towards the tip. In some individuals the sacral patch is slightly darker especially at the bases of the hairs. The whiskers are white, often dirty-white, and frequently brownish at the tips. The throat is purer white and white hairs also occur about the mouth. The ventral surface of the trunk, the whole upper limb and the remaining parts of the lower limb are jet-black like the back.

The hair is of medium length, but varies considerably in individuals. It is usually short on the mid-dorsal region and on the pale rump-patch. It is long on the nape, shoulders and flanks, but not so long as in highland races. Hair is sparse on the ventral surface and not so long as on the flanks. The whiskers are of moderate length, usually concealing the lower half of the ears only. The tail is closely covered with short hairs, except at the tip, where it may be longer. There is no well-marked terminal tuft in most specimens.

Pigmentation of the skin is the same as that described for the species, but the ventral surface may not be so heavily pigmented in some individuals. The face is dark purplish-black, whilst the ears and the naked parts of the hands and feet, naked perineal skin and also the callosities are jet-black.

Adult female. Similar to the male; certainly no paler or browner as supposed by Elliot. She is usually slightly smaller; has shorter whiskers and the characteristic white triangular patch on the pubes.

Young. The new-born is definitely paler than the adult; usually some shade of dark grey in general bodily colour. The pale rump-patch is not present at first, but appears as a patchy discoloration at about the age of four months. The areas later fuse to form a continuous patch. The crown is also the same in colour as the body at first, the brown colour appearing later than the rump-patch. There are some sparse black brow-hairs. The whiskers are very short, but white from the first. They grow considerably in length during the first three months. The hairy coat is fairly uniform in length and of a soft downy texture quite different from the adult hair. The naked pigmented areas are much more pallid than in the adult, the deposition of the pigment occurring slowly during the first six months or so, by which time the full dark colour is to be seen.

In individuals about one third grown the adult coloration of hair and skin is usually fully developed, but the hair is still of a softer texture than in the adult, though less silky than in the new-born. It is not yet known at what age the white pubic patch develops in the female, but this is certainly before puberty, as it is quite evident in adolescents. Puberty probably occurs at about the age of three years, though exact data are not yet available.

Measurements

Locality	Sex	Weight Kg.	Head and Body	Tail	Ear	Hind-foot	Remarks
Annasigalla, Matugama, W. P.	♂	5.89	555	763	31	170	
do.	♂ old	7.7	648	745	37	167	
do.	♂	6.34	558	693	34	160	
do.	♂	7.14	558	788	34	172	
do.	♂	5.56	540	730	38	161	
Hiyere, S. P.	♂	4.6	497	—	34	153	
Matara District, S. P.	♂	—	442	685	33	149	Semialbino
do.	♂ juv.	—	380	542	37	130	
Hiyere, S. P.	♂ juv.	2.75	402	546	39	131	
do.	♂ inf.	0.8	289	400	29	95	
Annasigalla, W. P.	♂ juv.	3.85	471	655	32	142	
do.	♂ juv.	2.72	397	490	34	128	
do.	♂ juv.	4.7	505	607	28	158	
do.	♀	5.21	525	750	31	150	
do.	♀	4.9	492	687	34	145	
do.	♀	4.6	520	720	31	142	
do.	♀	4.3	488	706	34	153	
Hiyere, S. P.	♀	4.3	478	679	40	140	Pregnant
do.	♀	6.6	529	702	29	152	Pregnant
do.	♀	5.0	523	—	36	162	
Matara District, S. P.	♀	—	441	685	33	149	
do.	♀	—	456	590	37	130	
Annasigalla, W. P.	♀ juv.	0.9	291	420	27	100	
do.	♀ juv.	3.74	483	641	27	144	
Hiyere, S. P.	♀ juv.	2.8	406	533	30	147	

Skull. Little need be added to the remarks made concerning the skull under the heading of the species as a whole. Comparison of the measurements of the skulls of *P.v.vetulus* and *P.v.nestor* shows little average difference in the size of the whole skull or any of its parts. There are many individual differences in detail, but no constant subspecific differences between these two forms.

Skull Measurements

	Kaluwara ♂	Kaluwara ♂	Matara ♂	Matara juv. ♂	Kaluwara ♀	Kosgoda ♀	Annasigalla ♀	Matara ♀	Matara ♀	Matara ♀
Max. cranial l. (Glabella-inion)	67.5	67	69	68	69	69	67.5	74.5	68	72
Max. cranial br.	54	54	58	53	55	52	52	57	56	54
Auric. ht.	38	40	36	39	38	38.5	36	32	35	38
Least frontal	34	37	38	40	31	33	37	32	43.5	34
Bimastoid	54	50	59	53	53.5	51	51	60	50	58
For. mag. l.	13	15	13	14	14.5	12	15.5	11.5	16	13
For. mag. br.	13	14	12	11.5	12	12	13.5	12	12	13
Palatal l.	29.5	30	34	28	30	31	31	37	28	37
Bizygomatic	65	62	72	60	69	63	63	73	54	69
Bipterygoid	30	26	35	29	29	30	32	36	28	32
Orbital ht.	21	20	20	19.5	21	21	19	22	19	21
Orbital br.	21	20	21	19	21	20	19	22	19	21
Nasal l.	14	13	17	12.5	16	15	14	17	12	19
Nasal br.	7	8	11	7.5	8	7.5	8	9	6	8
Upper tooth row	22	20	27	19	26	23	22	28	24	27
Across m. 2.	29	27	32	25.5	31.5	29	28.5	31.5	28	30
Condylar ht.	33	35	42	31	39	34	35	42	31.5	38
Mand. l.	60	56.5	69	55	57	59	60	65	47	67
Bigonial	51	44	55	40	50	50	48	54	39	54
Lower tooth row	28	22	32	17	27	24	25	32	28	30

Geographical distribution. The present subspecies is limited to the wettest part of the lowlands of Ceylon, namely, the undulating tract between the mountains and the coast on the south-west and south, from the Kalu-ganga river in the north to approximately a line drawn from near Ranna on the south coast (between Hambantota and Tangalle) to the east of Balangoda in the foot-hills. The rainfall in this area averages between 75 and 200 inches per annum mostly falling during the south-west monsoon, so that it corresponds in this respect to the Malabar tract of Southern India. It is not surprising therefore that this area has given rise to a race that is in many respects externally similar to the form occurring in Malabar. Both are jet-black in coat colour for example. Inland *vetulus* ascends the hills for some distance, and meets the territory of the truly highland form

monticola. There seems to be no specimen indicative of mixing
between these two forms, unless the specimen labelled as a Bear
Monkey by Pocock from Adam's Peak is thus considered.[1]

On the other hand I have received several verbal statements to the
effect that the two animals have been observed in the same localities at
considerable heights. There is no definite evidence regarding the
maximum altitude colonized by *vetulus*, but the animal is definitely
known from Balangoda (1,750 ft.) from the Ratnapura district (120-
2,000 ft.) and the Udugama Hills (3,000 ft.). The range of this form
seems to skirt the western edge of the Adam's Peak Range, but,
whereabouts it meets the territory of *nestor* in the north is, again,
not precisely known. Probably these two forms mix in the hinterland
of the valley of the Kalu-ganga, where the rivers are not wide enough
to prevent the monkeys crossing them. Such crossing, however,
must be of very rare occurrence since all the races of the Purple-faced
Monkey are very local in their wanderings.

In addition to the localities already mentioned specimens of this
subspecies have been obtained from Annasigalla, Matugama in the
Kalutara district (W.P.), Kottawa (S.P.), Matara district (S.P.),
Hiyere, near Galle (S.P.), Hikkaduwa, Galle district (S.P.), and in
the Pasdun korale. Albinistic specimens of this race appear to be
common in the Udugama Hills (up to 3,000 ft.) in the Matara dis-
trict, whilst other specimens of this type in the Colombo Museum
were obtained from Hikkaduwa (S.P.) and Baddegama (S.P.). Ten-
nent (1861) mentioned white specimens from Tangalle (S.P.)

2. Pithecus vetulus nestor (Bennett)[2]

The Western Purple-faced Leaf-monkey or Dusky Wanderoo

Semnopithecus nestor	1833 Bennett, *P. Z. S.*, p. 67
Cercopithecus nestor	1844 Templeton, *Cat. Singhalese An.*, p. 1
Vetulus nestor	1862 Reichenbach, *Vollständ. Naturgesch. Affen*, p. 326, Pl. XXII
Semnopithecus kelaarti	1876 Schlegel, *Monogr. des Singes*, p. 52
Pithecus vetulus nestor	1923 Hinton, *Ann. Mag. Nat. Hist.*, (9) XI, p. 510
	1926 Phillips, *Ceylon J. Sci.* (B) XIII, p. 274
Pithecus vetulus phillipsi	1923 Hinton, *loc. cit.*, p. 510
Pithecus senex nestor	1928 Pocock, *J. Bombay Nat. Hist. Soc.*, XXXII, p. 502

This is the common Leaf-monkey of the district around Colombo,
and is therefore the race most commonly seen in captivity and the

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Footnote 1 See page 70.
[2] This form was figured by Tennent and the figure copied and enlarged in Cassell's Natural
History, p. 97. Tennent's figure is wrongly labelled *Presbytes priamus* and this error was
repeated in Cassell.

one most accessible for study in the living state. Wild examples are frequently caught within four or five miles of the capital and are quite commonly sold as young animals for pets. It is the smallest, of the Purple-faced Monkeys.

Type. Bennett's type was a young male labelled merely ' Ceylon '. It is in the British Museum (B.M. no. 55.12.24.12). It was received alive by the Zoological Society of London, and died before attaining its permanent dentition. According to Hinton and Pocock the specimen is brown in general colour, no doubt due to fading. The type of Hinton's *P.v.phillipsi* was a fresher specimen received by the British Museum from Mr. W. W. A. Phillips, along with some others. all of which were obtained from the Panadura neighbourhood north of the Kalu-ganga. This type was an adult male (B.M. no. 28.1.19.1) and was collected at Gonapola in the Panadura district (W.P.). It appears therefore that Hinton in describing a new subspecies under the name *phillipsi* was merely sorting out the fresh, unfaded material and relegating the old brownish skins to Bennett's *nestor.* The name *phillipsi* therefore becomes a synonym of the earlier *nestor.*

Material examined. The present account is based on the examination of numerous living and freshly dead specimens both wild and captive. A large series of skins in the Colombo Museum has been used for comparison only.

External characters: adult male. The normal, general coat-colour of adults of this subspecies is a uniform grey, varying in individuals from a dark silvery or leaden grey to a dark iron grey. Brownish tints are only produced by fading and in the living are only seen just prior to and during the moult. Brown appears rapidly in dried skins. The grey normal tint occurs on the upper back, flanks, shoulders, upper arms, thighs, and on the ventral aspect of the trunk. It is slightly darker on the upper back and shoulders than elsewhere.

The brown cap is lighter and more conspicuous than in *P.v.vetulus*, the hairs on the crown being yellowish-brown and extending thence on to the nape for some distance, where they are even paler,—a light buff in the palest individuals. The cap is separated from the whiskers only by a linear tract of black hairs. These black hairs are a lateral continuation of the black, brow hairs, which are not very conspicuous in this race. The whiskers are well developed and pure white. The hairs on the chin and throat are dirty-white. The pale rump-patch is an ashy-grey, darker than in *P v.vetulus* and not so sharply defined from the dark hairs of the surrounding parts. The pale hairs extend out on to the buttocks and postero-lateral parts of the thighs as far as the knee and also for a few inches along the dorsum of the tail.

The rest of the tail is a darker grey, but not so dark as the body, except at the tip, where it becomes nearly white. The forearms and lower legs are darker than the more proximal parts, and the darkening increases distally until on the dorsum of the hand, fingers, feet, and toes the hairs are almost or quite black in colour.

The length of the hair is much the same as in the typical form, and as in that form it varies considerably in individuals. It is longest on the nape, upper back and flanks. It is short on the rump-patch and on the crown. The tail is comparatively thin (average 20 mm. across at base) and the hairs are short and closely set, except at the tip, where a terminal tuft occurs. The brow-hairs are shorter than in the highland races. The whiskers are well developed in the male, but do not conceal the upper half of the ears. The ventral surface of the neck and trunk are sparsely haired as in *P.v.vetulus*.

Pigmentation of the skin is the same as has been described for the species.

Adult female. Similar to the male; no paler and no browner normally. She is smaller in bodily size and has shorter whiskers more closely applied to the head. The white patch on the pubes below the callosities is well marked.

Young. The new-born differs considerably from the adult. The youngest specimen examined was five days old. In this there was no skin pigmentation. In another individual ten days old the general colour of the body hairs was a very light silvery grey. This colour affected practically the entire body, there being no crown- or rump-patches, and no darkening on the limbs. The whiskers, however, were white, but were very short and closely applied to the head. The black brow hairs were also present, but again, very short. The hair in general was soft and silky in texture throughout. The skin pigmentation in this individual was only just becoming evident. The face was a dirty flesh-colour, but traces of pigment were commencing to deposit and giving rise to a dusky tint in the ears and on the palms and soles only.

A somewhat older male specimen (Plate V) which first came under observation in April, 1938, was about six weeks old and weighed 17 ozs. It was brought up on the bottle and lived till July, 1933. During this time it went through some very important changes in external appearance, and increased in weight up to a little over 20 ozs. The general colour at first was a light slate-grey all over, with the forearms, hands, and feet slightly darker than the rest of the limbs. There was no indication of the brown cap or of a pale rump-patch. There were some short white hairs around the mouth and on the chin and cheeks. The ventral surface was very scantily clothed. The

tail was well haired and slate-grey in colour. Most curious was the state of the skin-pigmentation. The face was slightly pigmented except around the mouth and chin. The pigment was such as to give a peculiar livid lilac hue to the parts. The ears were bluish in colour, whilst the naked parts of the hands and feet and also the skin on the forearm were somewhat darker. There was no pigment on the chest, belly, genitalia or callosities, the last named being bright pink. The glans penis was completely covered by the prepuce, the latter not being retractile. This individual had a definite scratch reflex, using its hand or foot to scratch the abdomen when the latter was stimulated in the region supplied by the last dorsal nerves.

During the succeeding three months the hair grew longer and darker and the whiskers more prominent. Towards the end of June pale areas were developing on the lower back, and these tended to fuse together to form a continuous patch. The old grey hair fell out and was replaced by the shorter light-coloured hairs. The black supraorbital fringe increased. The face was still lilac in colour and was paler round the eyes, and still unpigmented around the mouth. There was as yet no indication of the brown cap.

A slightly older male specimen purchased about this time was much darker in general colour and had the continuous though indistinct rump-patch; the crown distinctly browner and the forearms, hands, crural region and foot quite black. The whiskers were well developed and dirty white in colour. There was the full facial pigmentation, but none on the ventral surface of the body.

In another young male about one-quarter grown the general colour of hair and skin was much the same as in the adult except that the front of the pileum was still grey, but the hair was softer in texture than in the full-grown animal, and the chest and belly were still devoid of pigment. Females at the same age already show the white patch below the callosities, but the skin beneath is unpigmented over this patch, though the belly and thighs are darkly coloured.

Measurements

Locality	Sex	Weight Kg.	Head and Body	Tail	Ear	Hind-foot	Remarks
Gonapola, W.P.	♂	—	495	712	33	164	
Homagama, W.P.	♂	—	500	620	30	156	
Veyangoda, W.P.	♂	—	500	655	36	181	
do.	♂	—	510	760	37	183	
Raygam korale	♂	3.6	518	730	33	159	d. in captivity
Kottawa, W.P.	♂	3.1	499	675	30	155	do.
do.	♂	3.8	549	570	32	172	do.
Bandaragama, W.P.	♂ juv.	—	450	620	35	138	
Veyangoda, W.P.	♂ juv.	—	420	600	36	140	

Locality	Sex	Weight Kg.	Head and Body	Tail	Ear	Hind-foot	Remarks
Homagama, W.P.	♂ juv.	1.4	381	536	28	125	d. in captivity
?	♂ inf.	0.8	260	429	32	88	do.
Dehiwela, W.P.	♂ nb.	0.6	231	339	28	84	do.
Horana, W.P.	♀	—	490	700	32	140	now in Brit. Mus.
Godigamuwa, W.P.	♀	—	530	700	31	182	
do.	♀	—	490	640	34	153	
Gonabendaduwa, W.P.	♀	—	560	770	36	153	
Piliyandala, W.P.	♀	—	560	750	36	157	
Homagama, W.P.	♀	—	565	690	34	155	
do.	♀	—	505	620	30	135	
do.	♀	2.19	444	640	35	160	d. in captivity
do.	♀	3.1	485	670	28	135	do.
Panagoda, W.P.	♀	—	512	662	30	145	
Veyangoda, W.P.	♀	—	480	674	37	147	
Homagama, W.P.	♀ juv.	1.75	414	615	30	137	d. in captivity
do.	♀ subad.	1.75	384	535	33	124	do.
do.	♀ inf.	0.9	228	395	29	98	do.

From the above table, compared with the corresponding table given
under *P.v.vetulus* it is gathered that although there is not much
difference in size between these two forms, the typical race tends to
produce slightly larger animals, adult males weighing up to 7 kg.
or a little more. This weight has not been recorded for even the
largest *nestor*. In both races the females are slightly less than the
males in size. From the table it will be noted also that the ear is
relatively larger in the young animal, reaching its full size long before
the body attains its maximum growth.

Moulting. A few words may be added here relative to the above
process as observed in several specimens of *P.v.nestor* kept in capti-
vity in Colombo. The moult seems to occur quite constantly in
December each year, varying by a week or two in different individuals.
For some time prior to this the body-hair has been looking worn and
somewhat dishevelled, and has faded from the normal grey to a brown-
ish-tint, though not so light in colour as the normal brown area on
the scalp. In one subadult female, hair was lost in large patches,
and some of the epidermis even desquamated during October and
November, 1932. By December, clean, new, grey hair was growing
and gradually replaced the lost hairs. The moult occurred at the same
time in a juvenile male, but there were no temporary bare patches.
An adult female began to fade rapidly in December, and new hair
was growing well in January, 1933.

Skull. The skull is not appreciably smaller than in *P.v.vetulus*.
As in that form there are many individual differences and no constant
subspecific characters. The general contour is smooth and rounded,
the muscular markings only being very evident in old males.

Skull measurements in P. vetulus nestor.

	Veyangoda ♂	*Veyangoda* ♂	*Raggam Korale* ♂ juv.	*Raggam Korale* ♂ juv.	*Labugama* ♂ juv.	*Pandaragama* ♂	*Walgama* ♂	*Raggam Korale* ♂	*Raggam Korale* ♂	*Pitiyandala* ♀	*Homagama* ♂	*Homagama* ♀	*Veyangoda* ♀	*Raggam Korale* ♀	*Veyangoda* ♀
Max. cranial l.	69	71	68	60	61	71	67	72	70	72	66.5	71	79	71	74
Max. cranial br.	52	57	55	51	49	56	51	56	52	55	55	55	58	48	55
Auricular ht.	36	37	37	40	34	33	37	37	37	41	39	36	37	34.5	35.5
Least frontal	32	29	39	39	38	34	33	35	28	22	39	18	24	51	53
Bimastoid	50	55	44	40	43	52	48	58	52	55	52	54	58	51	53
For. mag. l.	15	14	17	13	15	12.5	14	14	15	15	13	15	14	13.5	16
For. mag. br.	14	14	15	13	13	12.5	13	14	13.5	15	15	13	14	13	14
Palatal l.	31	34	26	20	—	31	31	32	35.5	38	30	35	37	33	30.5
Bizygomatic	61	67.5	53	45	47	66	58	72	67	73	64	71.5	72	68	65
Bipterygoid	29	31	26.5	21	18	31	27	34	30.5	32	29	28	34	32	32
Orbital ht.	18	18	18	17.5	17	20	19	20	20.5	19	19	21	21	20	21
Orbital br.	19.5	20	17	16.5	17	20.5	18	22	21	21	20	21	20	22	21
Nasal l.	12	14	12	9	9	14.5	15	17	16	19	14	21	19.5	16	15
Nasal br.	7	8.5	6.5	5	5	8	8	8	9	10	7	8	8.5	8	8
Upper tooth row	23	26	19	10	10	26	20	26	25	25.5	22	27	27.5	27	26
Across m2.	29	30.5	22.5	22	21	31	28.5	34	30.5	34	30	31.5	32	31	28.5
Condylar ht.	32	36.5	29	18	16	37	33	39	41	42.5	30	39	43	40.5	37
Mandibular l.	59	66	50	38	41	64	56	66	67	70	58	68	69.5	66	63
Bigonial	48	50	36	29	31	53.5	51	54	49	53	46.5	49	59	54	49
Lower tooth row	25	32	21	11	12	30	21	30	29	28	21	28	31.5	30	28

· *Geographical distribution.* The range of *P.vetulus nestor* occupies
an area within the western lowlands of Ceylon where the annual rain-
fall is rather less than in the area inhabited by the typical subspecies.
The average rainfall in the coastal parts of this area is 75 to 100
inches per annum, but increases in the foot-hills up to 200 inches,
e.g., at Kitulgala. The exact limits of the range of this form are not
yet completely worked out, but the following facts are known. In
the south the distribution is limited by the Kalu-ganga, which sepa-
rates this form from the last. On the north the range is less definite.
At the coast it extends a little way north of Colombo, but further
inland it ranges further to the north, for it is known from Veyangoda
and the neighbouring districts. Still further in, it probably reaches
as far north as Kurunegalla, but whether it extends beyond there, along
the northern limit of the hills is unknown. It is possible that it now
extends or has recently extended as far as the boundary of territory
now occupied by *P.v.philbricki.* The present race ascends the hills
for some considerable distance, but its exact limits in this direction
are unknown. Specimens have within recent years been obtained
from the region around Kegalla (633 ft.), Ruwanwella (180 ft.), and
Kitulgala (1,000 ft.). Originally Wanderoos were to be found around
Kandy (1,687 ft.), but they appear to be absent nowadays. Animals.
from this altitude would probably be intermediate in character
between *nestor* and *monticola.*

In addition to the localities already enumerated specimens have
been recorded from Homagama, Kottawa, &c. (all in the Raygam
Korale, W.P.), several places in the Panadura district and from various
localities in the Kelani Valley. Albinistic specimens are known from
Ruwanwella and Mawanella. The white monkeys referred to by Ten-
nent (1861) as being found between Ambepusse and Kurunegalla would
undoubtedly be referable to this subspecies.

3. Pitheous retulus montioola (Kelaart) (Plate VIII)

The Highland Purple-faced Leaf-monkey,
Great Wanderoo or Bear Monkey

The Bear Monkey	1840	Forbes, *Eleven years in Ceylon*, II, p. 144
Presbytis cephalopterus var. monticola	1850	Kelaart, *J. R. Asiatic Soc.* (Ceylon br.) II, no. 5, p. 321
	1852	idem, *Prodr. Faunae Zeylan.*, p. 2
Presbytis ursinus	1851	Blyth, *J. Asiatic Soc. Bengal*, XX, p. 155
	1852	Kelaart, *Prodr. Faunae Zeylan.*, p. 2
	1861	Tennent, *Nat. Hist. Ceylon*, p. 9

Vetulus ursinus	1862 Reichenbach *Vollständ. Naturgesch. Affen,* p. 128
Semnopithecus ursinus	1867 Hutton, *P. Z. S.*, p. 949
	1876 Martin Duncan, *Cassell's Nat. Hist.* I, p. 98
	1878 Anderson, *Anat. & Zool. Res.*, p. 24
	1888 Blanford, *Fauna Brit. India, Mammals,* p. 36
	1896 Forbes, *Handb. to the Primates,* II, p. 122
Pygathrix cephaloptera monticola	1913 Elliot, *Review of the Primates,* III, p. 71
Pygathrix ursina	1913 Elliot, *loc. cit.*, p. 74
Pithecus ursinus	1918 Wroughton, *J. Bombay Nat. Hist. Soc.,* XXV, pp. 556 et 561
	1926 Phillips, *Ceylon J. Sci.* (B) XIII, p. 278
Pithecus senex monticola	1928 Pocock, *J. Bombay Nat. Hist. Soc.,* XXXII, p. 502

Sinhalese : *maha vandhura*

Tamil : *periya mundi*

The so-called Bear Monkey is the large highland race of the Purple-faced Monkey in Ceylon. It received its popular name on account of the shaggy nature of its fur and its large size, which at a distance caused the animal to be mistaken by Major Forbes for a Sloth-Bear. Originally common on the higher hills, this animal has since the opening up of tea estates become very rare. Its destruction is largely due to the estate coolies, by whom the animal is eaten. It is now found in troops only on the highest mountain ranges where there is suitable jungle. Its distribution is therefore very local, and it is seldom seen on account of its shyness and the impenetrability of the jungles in which it lives.

Type. The Bear Monkey was originally distinguished as different from the low-country Wanderoo by Major Forbes. Kelaart is supposed to have sent the first specimen, which he obtained at Nuwara Eliya (6,185 ft.), to Blyth in Calcutta. Elliot states that the type is no longer to be found in the Calcutta Museum. According to Pocock the British Museum also possesses a specimen forwarded by Kelaart, but this was too old and worn to be of any value to the systematist. Very few specimens have been obtained since Kelaart's time, so that few museums anywhere in the world are in possession of material. Besides the specimen of Kelaart's already referred to, the British Museum only possesses three skins, two collected by Major E. W. Mayor from Hakgala (6,210 ft.) and Pattipola (6,200 ft.) for the Bombay Natural History Society's Mammal Survey and another old specimen from Adam's Peak sent by S. B. Bell. Mr. Phillips informs me that this last specimen, which he has examined, is not typical of *P.v.monticola,* but intermediate between it and *P.vetulus vetulus.*

Material examined. The present account is based mainly on the examination of three complete freshly-injected specimens sent from Hakgala (6,210 ft.) by one of the collectors of the Colombo Museum (November, 1933). These have been compared with a series of four skins from the Colombo Museum collection. A skull from a large female shot on the Elk Plains (6,000 ft.) was kindly lent to me by Mr. G. M. Henry. Six other skulls were loaned from the Colombo Museum.

External characters : adult male. The Bear Monkey is considerably larger and more sturdily built than either of the lowland races. Pocock is quite erroneous in concluding from his measurements that the supposed larger size is merely an appearance due to the great length and thickness of the hairy coat. As accurate linear measurements and body-weights of full-grown animals are now available there is no doubt in the matter. From the tables given in this paper it will be apparent that the heaviest lowland specimen of *P.vetulus* does not reach within five pounds of a full-grown Bear Monkey [1]. The adult male *monticola* seems to weigh 20 lbs. (*i.e.*, 9 kg.) fairly constantly.

The general body colour of *monticola* is much the same as in *nestor*, but tends to be somewhat darker in most individuals. The whole of the dorsal surface is fairly uniformly coloured. There is typically no pale rump-patch, though a few hairs around the root and along the dorsum of the tail are sometimes paler than elsewhere. There is no terminal frosting of the hairs, and no sharp demarcation of a pale area from the surrounding regions. The brown cap is also indistinct. The pileum is certainly browner than elsewhere, but the brown is much darker than in the lowland animals. The longer hairs on the nape, however, may tend to a buffish tint, thus forming in some individuals, a transverse pale band extending from ear to ear and fusing laterally with the whiskers. The black brow bristles are well developed. Laterally they extend out as a black, triangular area between the pileum above and the whiskers below as far back as the ear. The base of this triangle is directed forwards and the apex is situated in front of the ear. In addition to this the ocular region of the face tends to be surrounded by short, stiff, black hairs continuous with the brow bristles. Thus there is a narrow median strip of these along the nose, sometimes expanding to form a rounded patch on the front of the external nose. Then around the lateral margins of the orbit there is a tract of longer, black hairs, directed laterally, lying medial to the whiskers and passing on to the face almost to the lower eyelid. Others

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[1] Mr. W. W. A. Phillips informs me that he has a record of *P.v.vetulus* weighing as much as 17 lbs. This is still some pounds short of the average adult *monticola*.

occur on the upper and lateral parts of the upper lip and cheek, forming a moustache. The edge of the upper lip has the usual quota of white hairs continuous at the sides with the whiskers. The direction of the black facial hairs is indicated in Fig. 8. A reversal will be noted on the bridge of the nose. The whiskers are dirty white, sometimes greyish in colour and are much longer and more thickly planted than in the lowland animals. They usually hide the ears completely. The hairs on the lower lip and chin are more greyish than in lowland races, and the same applies also to the hairs on the throat. The upper parts of the limbs are the same colour as the body. The forearms and knees are darker, almost or quite black. The dorsum of the hands and feet is also clothed with black hairs. From the feet, black hairs extend upwards on to the lower half of the posterior surface of the crural segment. The hands and feet differ from those parts in other races in being relatively broader and shorter. The same characters are also shared by the fingers and toes.

One of the most characteristic points in the Bear Monkey is the great length and thickness of its hairy coat. This renders the animal very imposing in appearance and causes it to look even larger than it really is. The hair on different parts of the body varies in length as in the other forms, but in each area it is proportionately longer than in all the other forms. The longest hair is on the flanks where the individual hairs may reach a length of 120 mm. The whiskers reach
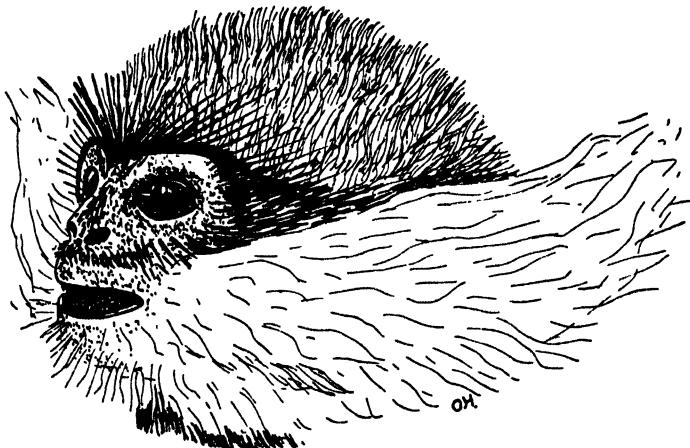
Fig. 7. Drawing of the facial characters of the Bear Monkey
(*Pithecus vetulus monticola*) for comparison with Fig. 8
Note the hair-reversal on the bridge of the nose.

almost the same length. The hair on the hinder part of the crown and on the nape is also long, but not so long here as in *P.v.johni*. The hair on the lower lumbar and sacral regions is shorter and woollier, and very thickly planted. That on the limbs is much longer than on the corresponding situation in any of the lowland forms. On the hands, feet, fingers, and toes it hangs over the edges to a considerable extent. The same happens around the callosities. The tail, which is relatively shorter and very much thicker (30 mm. in diameter), especially at the base, than in any of the other subspecies, is fairly closely haired, but in the proximal third the hair is rougher and woollier, like that on the sacral region. There is no tuft at the extremity and the hairs are not paler here than on the rest of the tail.

Skin pigmentation differs in several important particulars from that described for *P.v.vetulus* and *P.v.nestor*. The face, ears, hands, and feet are pigmented as in the other forms. The margin of the anus and callosities are also pigmented, but a triangular patch of naked skin between the callosities is unpigmented. The scrotum and prepuce are black, but the inturned layer of the latter is unpigmented. In some specimens there is a little pigment on the glans penis itself. The scalp and lower back are unpigmented, but the tail is pigmented from the root onwards. The ventral aspect of the body also lacks pigment except on the nipples and as a slight dusky tinge around them and a similar tinge on the pubes. On the upper limb, pigment extends from the hand up the forearm as far as the elbow: but on the lower limb pigment only reaches as far as the ankle.

Adult female. Similar to the male, but somewhat smaller. There is no sexual difference in general bodily colour. The white patch on the pubes below the callosities is present, but somewhat masked by the long and woolly character of the neighbouring hair.

Young. At present unknown.

Measurements

Locality	Sex	Weight Kg.	Head and Body	Tail	Ear	Hind-foot	Remarks
Hakgalla	♂	9.0	549	681	25	170	
do.	♂	9.0	556	702	37	164	
do.	♂ subad.	6.12	513	601	39	139	
Pattipola	♂	9.0	571	646	—	168	From Pocock (Brit. Mus.)
Bogawantalawa	♂	9.2	590	700	36	166	Colombo Mus.
Hakgalla	♀	7.5	516	646	—	156	From Pocock (Brit. Mus.)
Horton Plains	♀	3.8	458	516	32	140	Colombo Mus.
Bogawantalawa	♀	8.75	565	645	36	170	do.

From the above measurements it will be evident that the Bear Monkey does not exceed its lowland relatives so much in its linear

measurements as would have been expected. Specimens of *vetulus* and even *nestor* come well within the normal range for *monticola* as regards body length, whilst in tail length they frequently exceed it. But one or two linear measurements of this kind are by no means sufficient to justify a pronouncement like that of Pocock already alluded to. Body weight alone is the best guide, and it is evident from this that the Bear Monkey is a more sturdily-built animal than any of the lowland forms. If girths were taken, as well as the customary head, body and tail lengths, misleading statements would be less likely to occur. The increased girth of the tail in the Bear Monkey is a noteworthy feature, and this also applies to the girth of the trunk and limbs, quite apart from the appearances brought about by the thicker coat of hair.

The ear is relatively smaller than in *vetulus*, but is bigger relatively in the younger animals than in adults.

Skull. The skull of the Bear Monkey, when full-grown, exceeds that of *vetulus* and *nestor* in all its measurements. The bony markings such as supraorbital ridges, temporal lines, and occipital crest are all better marked than in them, especially in the adult male. There is a bigger area for the temporal muscles as indicated by the greater tendency for the temporal ridges to ascend toward the vertex (cf the least-frontal-width in the following table). The constancy in size and rotundity of the foramen magnum is a noteworthy fact in the table of measurements.

Skull measurements in Pithecus vetulus monticola

	Hakgalla ♂	Boga-wan-talawa♂	Boga-wan-talawa♀	Horton Plains♀ juv.	Elk Plains♀
Max. cranial l.	79	78·5	74	71	80
Max. cranial br.	64	62	57	56·5	61·5
Auricular ht.	44·5	41	33	36	37
Least frontal	38	19	23	37	27
Bimastoid	61·5	64	57	54	59
For. mag. l.	16	18	15	15	16·5
For. mag. br.	14	14	14	14	14·5
Palatal l.	35	40	36	28·5	37
Bizygomatic	78·5	81	76	64	77
Bipterygoid	33	39	36	28	37
Orbital ht.	22·5	20·5	22·5	21	21·5
Orbital br.	22	20·5	20·5	20	22
Nasal l.	16	16	18·5	12	16
Nasal br.	9	11	10	7·5	9·5
Upper tooth row	30	29	26	16	29
Across m 2.	35	35	31	28·5	34
Condylar ht.	36	50	42	33·5	44
Mandibular l.	ˋ70	76	67	56	72·5
Bigonial	50	64	56	52·5	60
Lower tooth row	36	34	30	24	32·5

Geographical distribution. The Bear Monkey has a more restricted range than any of the other races, and even within these limits it is now rare and only locally represented. Its present status may be described as consisting of a number of families or troops occupying well-known spots from whence it never wanders, and where the only suitable jungle left in the hills is situated. Rainfall is everywhere heavy (200 inches or more per annum) but varies considerably in different localities.

The range is confined to the more southerly parts of the central mountain-cluster of Ceylon, *i.e.*, to the ranges running mainly in an east to west direction. It does not appear to descend anywhere below 3,000 ft., and most of the troops live at a much higher altitude than this (*e.g.*, 6,000 ft. or more). Its southern range extends down to the 3,000-foot level on the southern slopes of the main mountain-cluster where it probably meets the northern limit of the range of *P.v. vetulus* somewhere above a line drawn from east to west through Balangoda. The western limit is formed by the Adam's Peak range and the area around Maskeliya. To the east of this the Bear Monkey occurs on the Bogawantalawa ridge, the Dolosbage Range, and on the high plateaux formed by the Bopats, the Horton Plains (7,000 ft.), Elk Plains (6,000 ft.), etc. Further north it once occurred around Nuwara Eliya (the type locality) and especially on the slopes of Pidurutalagalla, the highest mountain in the island (8,292 ft.). It still occurs fairly plentifully on Hakgalla (5,600 ft.). It may extend as far east as the Namunukula Range (Namunukula 4,480 ft.) in the Badulla district, though this is uncertain. To the north the range is limited by the valley of the Mahaweli-ganga in its early east to west course to the north of Hanguranketa. This river would appear to separate the territory of the Bear Monkey from that of the next race, *P.v. philbricki*. The best known troops are those on Hakgalla, on the Horton Plains, the Bopats (6,000 ft.) and at Pattipola (6,210 ft.). The troops around Nuwara Eliya are probably almost extinct, but they have been observed on an abandoned tea estate at Nanu-oya. Albinos referable to typical *P.v.monticola* have not been definitely recorded.

4. Pithecus vetulus philbricki Phillips

The North-eastern Purple-faced Leaf-monkey

Pithecus philbricki, Phillips, 1927, *Ceylon J. Sci.* (B) XIV, p. 57
P. senex philbricki, idem, 1929, *Ceylon J. Sci.* (B) XV, p. 122

This race* is the least satisfactorily defined of all the Ceylonese *Pitheci*. The original description given by Phillips was insufficient to

separate it from other races and resolved itself mainly into the fact that the animal had a relatively longer tail than in the other forms. Examination of all the available material, however, has convinced me that this form is undoubtedly separable, though its characterization is not so complete as with the other forms. It is probably to be regarded as a phylogenetically young type still undergoing evolution. Its parent was probably a Bear Monkey, to which form it is undoubtedly most closely allied.

The scientific description of this animal did not appear till 1927, though Mr. G. M. Henry of the Colombo Museum informs me that he was aware of the existence of large dark Wanderoos in the Trincomalee district as long ago as 1913, when he shot a large specimen. The Wanderoos mentioned by Templeton (1844 *b*) and Kelaart (1852) as occurring in that district and which differed from the common Entelloid form of the neighbourhood were certainly not the present animal, but abnormal specimens of the Entelloid (*P.entellus thersites*).

P.v.philbricki is the largest of all the Ceylonese races of the Purple-faced Monkey. Originally believed to be confined to the dry lowland plains of the Trincomalee district, it is now known to ascend the hills to the south up to considerable altitudes.

Type. Adult male from Kantalai (200 ft.) collected on September 14, 1925, and forwarded by the Colombo Museum to the British Museum (N. H.). Two other specimens were forwarded at the same time. Others from the same locality were deposited in the Colombo Museum.

Material examined. I have not yet had the opportunity of seeing a living or freshly dead specimen of this race.[1] The nearest approach to this was a freshly prepared skin sent to me from Gammaduwa by Mr. W. W. A. Phillips. At the time I received this specimen there was no evidence of fading, and it is still possible to make out the distribution of skin pigmentation. In all I have examined six skins of this race. The corresponding skulls have also been studied.

External characters: adult male. The most striking fact about this race is its large size. It attains the proportions of the Bear Monkey and frequently exceeds it. In general build, however, it is less robust, and has more the appearance of a very large *nestor*. The troops that occur in the hills of the Matale district approach nearer to the Bear Monkey in type, but are nevertheless distinguishable. The weight of

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[1] Since going to press I have had an opportunity of examining a living, subadult female of this race and my observations on this animal amply confirm the description given in the succeeding pages.

the adult male probably reaches as high as 24 or 25 lbs. The subadult male from Gammaduwa weighed 22 lbs. The lowland specimens are certainly no smaller.

In general colour *philbricki* is almost identical with *nestor*, and, as in that form the colour darkens gradually on the limbs, till on the fore-arms, hands, and feet the hair is almost pure black. The pileum has the usual brown coloration. This is lighter than in *monticola*, but not quite as pallid as in *nestor*. The occiput and nape are paler than the forepart of the crown. The whiskers are pure white. They are separat-ed from the cap by a triangular black area as in *monticola*. The brow hairs are well developed and there are also black hairs on the median line of the nose and around the orbital margins. These are not so heavily developed, as a rule, as in *monticola*. As in *monticola* there is a black moustache and not many white hairs on the upper lip. The rump-patch is inconspicuous, but not absent. It is better developed than in the Bear Monkey, the hairs being slightly shorter and some-what paler than the hairs of the middle of the back. The patch is not well-defined at the margins, and does not extend on to the buttocks or tail. The tail is leaden grey for three quarters of its length, but paler at the tip. The tail is, in most specimens though not all, per-fectly white at the tip.

The texture and length of the hair is different from that of *monticola*. It is long on the shoulders, upper back and flanks but not so long as in the Bear Monkey. On the sacral region it is short. The hair is of medium length on the pileum, but longer on the nape, where laterally it is continuous with the whiskers. The throat hair is comparatively short, as is also the case on the ventral aspect of the trunk. The tail is closely covered with smooth hair, the diameter of the tail near the root being only 15 mm. The hairs towards the tip are longer, but cannot be said to form a tuft. On the limbs the hair is but little longer than in the corresponding situation in *nestor*, and the same applies to the hands and feet. In texture the hair is in general smoother and more silky than in *monticola*. The individual hairs, moreover, are straighter than in that form.

In skin-pigmentation *P.v.philbricki* approaches *nestor* more closely than *monticola*. The face, ears, naked parts of hands and feet and also the callosities and the naked area around the anus are coloured as in *nestor*. The scalp is pigmented in its anterior half only. Behind this the whole of the back and flanks are devoid of pigment. The throat, chest, and abdomen are, however, well darkened, especially around the nipples. The tail is pigmented practically throughout. The

hand and forearm are pigmented up to the elbow. The brachium is pigmented on its flexor and extensor surfaces. The lower limb is pigmented throughout.

Adult female. Similar to the male, but smaller. The triangular pubic patch is very large and conspicuous. It extends backwards between the callosities, around the vulva, and is continuous with some sparse white hairs on the otherwise naked perineal skin. A convergence is formed posterior to the vulva. The hairs on the sides of the vulva are directed backwards. Those on the perineal area pass towards the mid-line and forwards.

The hair on the hands and feet is not so black as in the male, being only slightly darker than on the forearm and calf, where it is no darker than it is on the body.

Young. Unknown at present, but probably similar to that of *nestor*.

Measurements

Locality	Sex	Weight Kg.	Head and Body	Tail	Ear	Hind-foot	Remarks
Kantalai, E.P.	♂	—	600	885	42	195	Type
do.	♂	—	616	820	35	179	
do.	♂	—	564	919	50	170	
do.	♂ juv.	—	443	695	40	150	
do.	♀ juv.	—	437	725	44	147	
do.	♀	—	536	795	45	165	
do.	♀	—	484	820	40	165	
Sigiriya, C.P.	♂	—	615	841	37	175	
do.	♀	—	640	770	35	175	
Gammaduwa, C.P.	♀ juv.	—	600	640	—	162	
do.	♂ subad.	9.97	603	768	33	174	

Skull. The skull of *philbricki* is very similar to that of the Bear Monkey, but even larger. In the adult male the muscular markings reach their maximum development for this species. The temporal lines, however, do not seem to ascend towards the vertex as much as in the Bear Monkey. The skull is more prognathous than in the other races, and coupled with this there is less outward bowing of the molar teeth. In the subadult male from Gammaduwa the canines are not fully erupted, and the occipito-sphenoidal junction is not ossified completely. At this stage the molar rows are bowed outwards. But in the fully mature male from Sigiriya the tooth rows are straight as in Entelloids. The same happens in the female, but not quite so markedly.

Skull measurements in Pithecus vetulus philbricki

	Kantalai ad. ♂	Gammaduwa subad. ♂	Sigiriya old ♂	Kantalai ♂ juv	Sigiriya ♀	Gammaduwa subad. ♀	Kantalai ad. ♀
Max. cranial l.	74	82	80	68	79	74	74
Max. cranial br.	62.5	60	59	54	59	61	58.5
Auricular ht.	41	44	40	34	41	34 .	34
Least frontal	32	21	23	36	27	32	29
Bimastoid	59	62	62	54	58	58	57.5
For. mag. l.	15	18	17	13	14	16	13
For. mag. br.	14	14	17	13.5	14	14	14
Palatal l.	40	39	38.5	28.5	34	32	37.5
Bizygomatic	79	81	81	64	77	71.5	75
Bipterygoid	35	36	33	30	33	30	34
Orbital ht.	24	21.5	21	21	21	22	21.5
Orbital br.	23.5	21.5	23	20	21	22	21.5
Nasal ht.	19	19.5	18	15	16	15	15
Nasal br.	9	9	10	6.5	8.5	7	8
Upper tooth row	28	28	28	22	28	26.5	29
Across m. 2.	33.5	35	34	29	31	33	32.5
Condylar ht.	46	44	48	37	38.5	38	44
Mandibular l.	71	77	76	58.5	67	63	69
Bigonial	58.5	61	64	44	61	53	60
Lower tooth row	36	34	35	24	34	31	33

Geographical distribution. P.v.philbricki was originally considered to be a local inhabitant of the lowland area around Trincomalee (E.P.) for a distance inland of some twenty miles or so. Recently it has been proved to occur over a much wider area including the hill region of the Matale district up to an altitude of 4,000 ft. or a little more. In all these parts, however, rainfall is low (60 to 80 inches per annum). To the south its territory is probably limited and separated from that of the Bear Monkey by the valley of the Mahaweli-ganga in its early east-to-west course from the hills. To the east the same river, in its later south-to-north course, separates the territory of *philbricki* from that of the Entelloid, *P.entellus thersites* in Bintenne. The East Matale hills drop suddenly on the east into this part of the river valley, and the present subspecies would appear to descend these slopes as far as the river-bank, a belt of low-country jungle some seven miles wide separating the foot of the hills from the river. The present animal has been observed at Girulupota within this belt and further north in the area around the Nitre Cave, which is at a higher altitude. Still further north in the Gammaduwa neighbourhood small troops of Wanderoos still occur. Mr. W. W. A. Phillips has sent to the Colombo Museum two skins taken from this region. One of these is noted to have been

shot in the jungle on Patnagalla (4,970 ft.) accompanied by five white companions, and one normally coloured individual. Another troop observed was composed of four or five normally coloured monkeys and one white one. Although the monkey is not now common in the Matale district proper, numerous former records of its occurrence in this neighbourhood are available. Kelaart's white monkey came from this region and was undoubtedly an albinistic specimen of this race. Those seen by Robert Knox were probably also of this type. To the north *philbricki* descends the rapidly-diminishing hills towards the Dambulla and Sigiriya neighbourhoods. Here it lives side by side with the Entelloid. A troop of large Wanderoos, including some white specimens was mentioned as residing on Dambulla rock by Rev. R. Spence Hardy (1853) and quoted later by Tennent. Around Sigiriya (C. P.) dark Wanderoos occur at Piduragalla (640 ft.) and these prove to be *P.v.philbricki*. In the lowlands to the north and north-east of this district *philbricki* has been obtained from the following localities :— Trincomalee (E. P.), Kantalai (E. P.), Nilaveli (E. P.), and Horowa-potana (E. P.), and has been observed at Minneriya (N.-C. P.) and Habarana (N.-C. P.). It probably also occurs on Ritigalla (2,400 ft.). In all of these localities the Entelloid is also common.

The western distribution of *philbricki* is quite undetermined, but, as mentioned under *nestor*, it probably meets and fuses with this form on the borders of the Kurunegalla district. The present race, however, is found much further north than *nestor*, but does not seem to occur as far west as Anuradhapura.

5. Pithecus vetulus johni (Fischer)

The Nilgiri Purple-faced Leaf-monkey, Hooded Leaf-monkey,
Nilgiri Langur or Malabar Wanderoo

Eiginer affenarten	1795 C. J. John, *Berlin Ges. f. Nat. Freunde* (Neu Schr.) I, pp. 211, 218
Cercopithecus johnii	1829 Fischer, *Syn. Mamm.*, p. 25
Semnopithecus cucullatus	1834 I. Geoffroy, *Zool. Voy. de Bélanger*, p. 38 et al.
S.johnii	1838 Waterhouse, *Cat. Mamm. Mus. Zool. Soc. Lond.* 2 ed., p. 5 et al.
S.jubatus	1840 Wagner, *Schreber's Saugethiere*, Suppl. I, p. 308, et al.
Presbytis cucullatus	1859 Blyth, *J. A. S. Bengal*, XXVIII, p. 283
S. (Kasi) cucullatus	1862 Reichenbach, *Vollständ. Naturges. Affen*, p. 101
Presbytis jubatus	1867 Jerdon, *Mammals of India*, p. 7
Pygathrix johni	1913 Elliot, *Review of the Primates*, III, p. 72

Pithecus johni   1918 Wroughton, *J. Bombay Nat. Hist. Soc.*,
                                XXV, p. 560
                            1932 McCann, *J. Bombay Nat. Hist. Soc.* XXXVI,
                                p. 624
P.senex johnii   1928 Pocock, *J. Bombay Nat. Hist. Soc.*
                                XXXIII, p. 503

The Malabar form of Purple-faced Monkey is a relic from the former connexion between India and Ceylon, and like other similar relics is confined to the wet western coastal tract of South India. It has been separated from the Ceylonese forms sufficiently long to have become very different in appearance from any of them, though approaching nearest to the form inhabiting the corresponding climatic zone in Ceylon, *i.e.*, *P.v.vetulus*. It is possible (see p. 30) that the differences between the Malabar form and the Ceylonese animals are sufficiently great for the former to be given full specific rank. This view is favoured by the fact that, being isolated, no intergrading occurs. *P.v.johni* appears to be suffering the same fate as the Bear Monkey, and is at the present time very rare and shy of human beings. In addition to the fact that lower castes of Tamils eat them, there is the further incentive to kill them on account of the beauty and value of their pelts. Specimens are rarely seen in captivity, though Flower (1931) records one which has lived for a considerable time in the Trivandrum Zoo.

This is the largest of all the members of the subgenus, reaching 29 lbs. in weight.

Type. No type appears to be known for this form, but the type-locality is given by Fischer as ' India orientali '.

Material examined. I have seen no living or fresh material of this monkey; but as fading does not appear to affect the black coat of this form, it may reasonably be concluded that the following account, based on the examination of four skins in the Bombay Natural History Society's collection, is not unreliable. Only one skull was forwarded to me with the above skins, and that is a very juvenile one. Pocock, however, gives measurements of three skulls, and these have been included in the table below.

External characters: adult male. This is the largest of the Purple-faced Monkeys, full grown adults weighing 25 lbs. or more. Elliot's statement that the Bear Monkey is a giant by the side of *johni* is quite wrong.

In general colour the Nilgiri Leaf-monkey is jet black, with no trace of grey or brown (cf. Gray, 1870). The black is uniformly distributed over the trunk, tail, and limbs. The only parts not black are the crown, whiskers, and occasionally a few hairs on the sacral

area. The crown is dark brown in front and lighter, almost yellowish posteriorly. This yellowish-tinge affects the long hairs on the nape also. There is a black brow-fringe, best developed laterally but not extending back between the pileum and the whiskers as in *monticola* and *philbricki*. There is, however, a median tract of black hairs on the nose, and also a moustache and a marginal fringe around the orbits. There are no white hairs on the face at all. The whiskers are the same colour as the fore part of the pileum, and there is no separation of the two by black hairs at the level of the ears. A few hairs on the ears themselves are brown, not black. Apart from a few black hairs on the lower lip, the chin and throat are clothed entirely with brown hairs continuous with the whiskers. These gradually darken on the neck and become continuous with the jet-black hairs on the chest. The sacral patch is not well marked, and sometimes absent, especially in immature specimens. A few hairs in the middle of the back are frequently frosted at the tip. Those around the root of the tail may be silvery throughout. The paler hairs, however, are mixed with normal black hairs, and there is no sharp definition of the sacral patch from the surrounding parts. The hair is darker in the mid-line than laterally in this region. The lighter lateral parts may extend as faintly paler areas on to the buttocks. A few hairs at the commencement of the tail may also be frosted, but the rest of the tail is black throughout, with no light hairs at the tip.

In length, although *johni* is a highland animal, its hairs fall far short of those of *monticola*. The hair over the greater part of the body though varying considerably in individuals is short, smooth, and glossy, and closely applied to the surface of the body. It is longest on shoulders and upper back and shortest on rump. The same is true of the limbs and tail, there being no tuft on the end of the latter. The hair on the crown and nape, however, is characteristic of this form in its excessive length. That on the vertex is shaggy and directed mainly backwards. Further back on the occiput, and still more so on the nape, it radiates over the shoulders as a cowl, the individual hairs being very long and wavy. This appearance has given rise to the obsolete specific names, *cucullatus* and *jubatus*.

The whiskers are of the same texture as the hairs of the cowl. They are long and shaggy, but not so full as in *monticola* or *philbricki*, though they usually hide the ears completely.

In the absence of fresh material it is impossible to give a complete account of the skin-pigmentation in this race. The naked parts

appear to be pigmented as in the other forms, but it should be pointed out that, according to Blyth (1847 *b*) the expression of the countenances of *johni* and of *cephalopterus* (i.e., *vetulus* or *v.nestor*) when alive is quite different.

As far as it is possible to judge from the dried skin, there seems to be some pigment on the scalp, but none on the dorsum of the trunk. The chin, throat, chest, and belly are pigmented as in *philbricki*. The tail is pigmented. The hands and forearm are also laden with pigment, but the brachium is not. The feet and crus agree with the hand and forearm. The thigh seems to bear pigment on its flexor aspect only.

Adult female. Similar to the male, but slightly smaller. The white pubic patch is present according to Pocock (1928 *a*), though it cannot be made out in two specimens marked as females borrowed from the Bombay Natural History Society. In another specimen labelled as a male, there are a few stray white hairs in the mid-line over the pubic region. Possibly the skins have been mixed up.

Young. Our knowledge of the young *johni* depends on statements made by Anderson and Pocock. From their accounts it may be inferred that this monkey passes through similar phases to that described in this paper under *nestor*, but that the general colour is black from the first, the black being distributed not only on the body, but also including the cap and whiskers. It was on these grounds that Pocock placed *johni* (and thence all the other Purple-faced Monkeys) in the Entelloid group. As the young *johni* grows older the brown cap appears as in *nestor*, and at the same time the whiskers evidently also become brown. The sacral patch is very late in developing, and may not appear at all. Pigmentary changes in the skin may be safely assumed to occur as in *nestor* as described above.

Measurements

Locality	Sex	Weight Kg.	Head and Body	Tail	Ear	Hind-foot	Remarks
Nelliampathy Hills, 3,500 ft.	♀	—	705	710	—	195	Coll. by A. M. Kinloch
do.	♂	—	645	764	—	181	do.
do.	♀	—	558	721	—	150	
Kukkal Shola, Palni Hills, 6,100 ft.	♀	9.9	609.5	812.8	—	177.8	
Brahmagiri Hills, 2,700–5,135 ft.	♂ juv.	4.5	515	721	35	148	Coll. by G. C. Shortridge
do.	♂	9.5	660.5	774	—	177.8	do.
Kumblacodie, Cochin, 3,500 ft.	♂	—	584.25	866	—	190.5	
Anamaad, South Malabar, 3,200 ft.	♂	—	571.5	939.8	—	197	

Further valuable measurements, including body-weights, of fresh specimens have been recently recorded by McCann (1933).

Skull. This is, according to all authors, larger and more robust than that of the low-country Ceylonese Wanderoos. The teeth too are proportionately larger. According to Anderson the interorbital breadth is less relatively than in *cephalopterus* and the palate more constricted. Further differences are given, *e.g.*, shorter symphysis menti, a less deep horizontal ramus and a narrower vertical ramus, and a greater bigonial breadth. I suspect, however, that as in the case of the other races, many of these distinctions would fall if a sufficient number of skulls were examined. Personally I have seen only one skull, that of a young male from Coorg obtained by G. C. Shortridge. This specimen is indistinguishable from a subadult of *nestor*.

Skull measurements of Pithecus vetulus johni

	Srimangala, Coorg ♂ juv.	Cochin ♂ juv.	Nilgris ♀	Cochin ♀
Max. cranial l.	?70	108	108	95
Max. cranial br.	60	—	—	—
Auricular ht.	40	—	—	—
Least frontal	43	—	—	—
Bimastoid	—	—	—	—
For. mag. l.	—	—	—	—
For. mag. br.	—·	—	—	—
Palatal l.	31	32	36	30
Bizygomatic	67	80	83	—
Bipterygoid	33	—	—	—
Orbital ht.	21	—	—	—
Orbital br.	20	—·	—	—
Nasal l.	15	—	—	—
Nasal br.	6	—	—	—
Upper tooth row	23	30	31	30
Across m. 2.	29	—	—	—
Condylar ht.	33	—	—	—
Mandibular l.	61	—	—	—
Bigonial	52	—	—	—
Lower tooth row	25 (incl. unerupted molar)	—	—	—

[Columns 2, 3, and 4 are taken from Pocock's table.]

Geographical distribution. The Nilgiri Leaf-monkey is confined to the wet Malabar tract on the west of South India. Here the rainfall averages per annum between 100 and 200 inches. This monkey does not descend so far as the coast, but appears to be limited to the hills above the 3,000-foot level.[1] Southwards it extends right to Cape

[1] McCann (1933) states that this is the case in the Palni Hills, but in the Tinnevelly Hills it descends to the foot of the hills.

Comorin, whilst its northerly range includes Coorg. Within this area its distribution appears to be very local as in the case of the Bear Monkey. It inhabits dense localized patches of jungle locally known as ' sholas ', which clothe the hillsides at intervals. Its range includes the Nilgiri, Anamalai, Brahmagiri, Tinnevelly, and Palni Hills, and the Western Ghâts. It also includes the Wynaad district. Its territory is overlapped from the east by that of the Entelloid (*P.entellus pallipes*).

SUMMARY AND CONCLUSIONS

The characters of the five forms of Purple-faced Leaf-monkey may be summarized briefly in the form of a table (Table I) whilst identification will be facilitated by reference to the key which follows (Table II).

[Table I. See page 85.]

TABLE II
KEY TO THE IDENTIFICATION OF THE PURPLE-FACED LEAF-MONKEYS

A. General colour black

    a. Whiskers white; rump-patch large and well-defined . . . . *P.v.vetulus*
    b. Whiskers brown; rump-patch small or absent   . . . . *P.v.johni*

B. General colour grey

    a. Size small (weight under 15 lbs.); rump-patch
       large; no black hairs on face   . . . . . . *P.v.nestor*
    b. Size large (over 15 lbs., usually much more);
       a' Colour darker; hair long and shaggy; rump-
          patch absent; tail short and thick   . . . . . . *P.v.monticola*
       b' Colour lighter; hair short and silky; rump-
          patch ill-defined; tail very long and thin . . . . *P.v.philbricki*

In closing I wish to tender my sincerest thanks to a number of helpers without whose assistance this account of the Purple-faced Monkeys could not have been satisfactorily completed. Firstly, 1 would express my gratitude to the Bombay Natural History Society for the generous way in which they have loaned to me their valuable specimens of Indian Leaf-monkeys. I wish to extend the same thoughts to the Calcutta Museum for the loan of their valuable specimen of *Semnopithecus senex*. In addition I must acknowledge the help I have received from several members of the staff of the Colombo Museum; to the late Director, Dr. J. Pearson, for much assistance and guidance in the matter of nomenclature; to the Acting Director, Mr. A. H. Malpas, for taking the photograph reproduced in Plate VIII; to Mr. G. M. Henry for the loan of a skull of *monticola;* to

TABLE I

Character	vetulus	nestor	monticola	philbricki	johni
Size	Medium (up to 15 lbs.).	Small (8–10 lbs.).	Large (20 lbs.)	Very large (22 lbs.)	Very large (25 lbs. or more).
Gen. colour	Black.	Grey.	Darker grey.	Grey.	Black.
Brow hairs	Moderate. Linear tract only between pileum and whiskers. None on face.	Same as vetulus.	Heavily developed. Triangular patch between pileum and whiskers. Extensions on to nose and around orbits. Moustache present.	Same as monticola.	Same as monticola, but no extension towards ears.
Pileum	Dark brown; hairs short.	Light brown; hairs short.	Very dark brown. Scarcely paler than back.	Same as nestor; hairs long.	Dark brown in front. Very light buff behind. Hairs very long.
Whiskers	White: moderate.	Same as vetulus.	Dirty white. Very long and full.	Same as nestor but longer and fuller.	Brown, same as pileum.
Rump-patch	Very sharply defined. Light silvery grey. Frosted on back.	Darker grey and less well defined. Extends to thighs	Absent.	Slightly marked. Ill-defined and dull grey. Not extending to thighs.	Slight frosting at base of tail in some individuals only.
Tail	Long: mole grey. No tuft.	Same: darker grey: Whitish at tip. Tufted.	Shorter but very thick. Light grey. No paler at tip. No tuft.	Very long and thin. Dark grey. Distinct white tip. No tuft.	Black throughout. No tuft.
Skin pigmentation	All naked parts (except glans penis). Scalp, lumbar region: most of limbs ventral surface of body.	Same as vetulus.	No pigment on ventral surface of scalp. Little on upper limb and thigh. Pigment on glans penis.	Similar to nestor, but less extensive on scalp. None on back.	?

Mr. E. C. Fernando, taxidermist, for much help in running through records of skins and skulls; and to Mr. L. de Fonseka of the Museum Library for similar help in verifying references to literature. Lastly, but by no means least, I must thank Messrs. W. E. Wait, C.M.G., C.C.S., W. W. A. Phillips, and H. Jameson for the assistance they have given me both verbally and in the matter of literature. I have found Mr. Wait's great knowledge of local geological conditions of great help in my work; whilst to Mr. Phillips I owe much of what I have learned regarding the range of the different forms and also for supplying me with his valuable records of measurements of monkeys in the flesh. Dr. H. Jameson, Superintendent of the Colombo Observatory, has kindly supplied me with information regarding rainfall in the different districts inhabited by the Purple-faced Monkeys.

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EXPLANATION OF PLATES

PLATE IV

The skull of *Pithecus vetulus*

Upper figures : norma frontalis and norma occipitalis of skull of *P.vetulus philbricki*, adult male from Sigiriya (C. P.)

Lower figures : norma lateralis and norma verticalis of skull of *P.v.philbricki*, adult female from Sigiriya (C. P.)

PLATE V

New-born male of *Pithecus vetulus nestor* from Dehiwala (W. P.)

PLATE VI

Adult female of *Pithecus vetulus nestor* from Raygam korale (W. P.)

PLATE VII

Albinistic individual (adult male) of *Pithecus vetulus nestor* from Mawanella,

Left : near view of face

Right : the complete animal

PLATE VIII

Recently killed specimen of Bear Monkey (*Pithecus vetulus monticola*), adult male from Hakgalla (C. P.)   •

PLATE IX

Map to show the distribution of the Ceylonese races of *Pithecus vetulus*

PLATE IV.
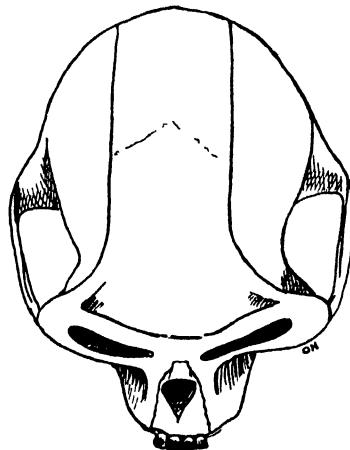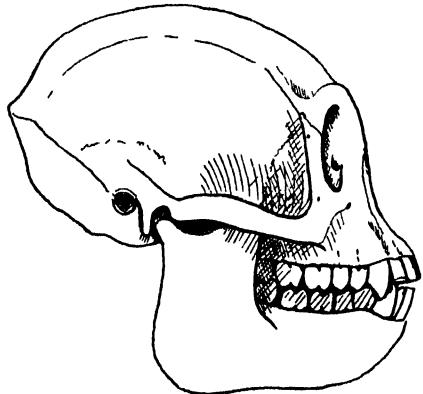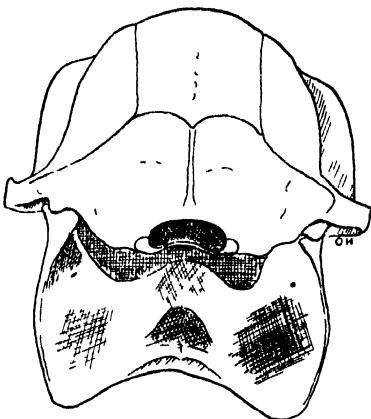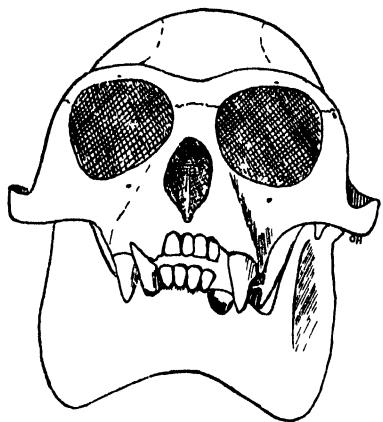
W. C Osman Hill del.

Skull of *Pithecus vetulus*

PLATE V

Pithecus ictulus nestor
New born male

Pithecus retulus nestor
Adult female

Pitl u° retulus nestor
Albinistic male

PLATE VIII

Pithecus retulus monticola

Adult male

PLATE IX

Map to show the Distribution of the Ceylonese Races of Pithecus Vetulus.

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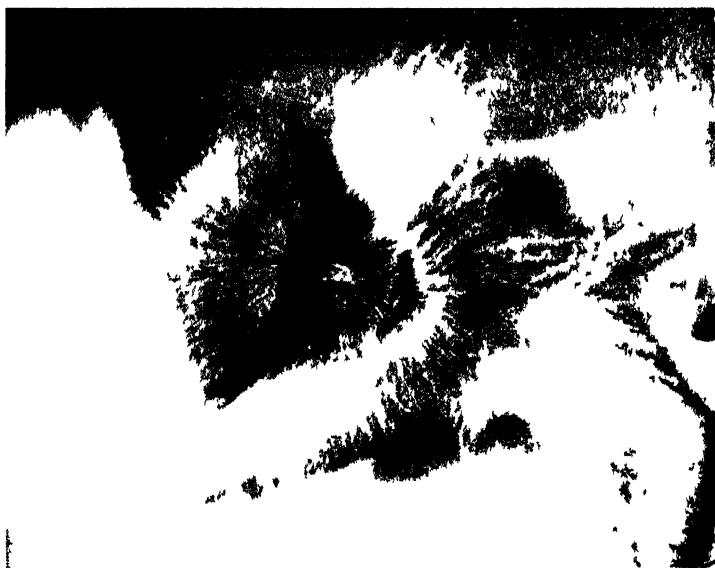
NOTES

1.   Some Apodal Larvae from Ceylon Waters

This paper deals with the larvae of various eels taken on the Pearl
Banks in the Gulf of Mannar, and from Wadge bank off Cape Comorin.
All were strongly compressed and possessed colourless blood. As they
ascended to the surface after dark and entered shallow water on the
continental shelf, they were probably in their final larval stages and
about to metamorphose. Such a view is supported by the occurrence
of this change within 6 days in a specimen captured on March 17,
1933, on the Pearl Banks. This larva was then strongly compressed
and had colourless blood. By March 22 it had red blood and by
March 23 had metamorphosed into an elver which was about 2 cm.
shorter than the larval stage.

Although the reproduction of European eels has attracted consider-
able attention, comparatively little is known concerning the larval
stages of Asiatic species. All Apodes breed in the sea and it is known
that the Anguillidae of Europe and America, although passing the
greater part of their lives in fresh water, are catadromous and have a
common breeding place in deep water, far from land approximately
between Lat. 48° W to 75° W and Long. 23° N to 30° N. It is also
thought that their larval period is three years. During this interval
they contrive to approach land either through the aid of ocean currents,
or by means of their own exertions, or by both and metamorphose into
unpigmented pelagic elvers when near their destination. Eventually
they enter fresh water, become pigmented and rank as young eels.

It is strange that the catadromous Anguillidae of the Atlantic do not
breed close to land, but not all marine eels are as particular in their
selection. I have already noted the capture of a gravid female
Leiuranus semicinctus which a ripe male had seized by the nape.
The pair were taken at a distance of about 12 miles from land at a
depth of 9 fathoms. (Deraniyagala, 1930, p. 107.) There are also
records of European marine eels breeding almost as close to land, so
it is not advisable to generalize from the habit of the Atlantic
Anguillidae.

In the tropical waters off Ceylon, invertebrates, fishes and turtles
reproduce throughout the year with two maximum periods, dependent
largely on the effect of the altering monsoon conditions upon the ocean.
The Ceylon Anguillidae are no exception to other marine forms.

One species *A.bicolor* MacClelland, is more or less uniform in the size of its adults and large specimens are extremely rare, the usual length being 550 mm. The other species *A.elphinstonei* Sykes, is highly variable in its dimensions.

The first species probably dies at sea after spawning once, but the variable size of the latter, which often exceeds a length of 1,000 mm. and a weight of 10. lb., suggests that many specimens return to fresh water after spawning. Elsewhere I have noted that the elvers of *bicolor* come in shoals during certain seasons and commented on the scarcity of those of *elphinstonei*, although the adults are by no means uncommon. Such scarcity might be due to only small numbers of this species spawning at a time, whereas *bicolor* migrates in large numbers.

Dr. Johannes Schmidt writing on December 12, 1929, stated ' I found pelagic elvers of *Anguilla bicolor* over great depths south of Ceylon but no larvae; these may come from the breeding grounds I discovered west of Sumatra where I found tiny larvae of both species. (*Anguilla bicolor* and *Anguilla elphinstonei*) '.

This letter implied the absence of elvers of *elphinstonei* from the pelagic depths south of Ceylon. It is probable that the breeding places of this species are comparatively close to land and the larvae metamorphose more rapidly than those of *bicolor*. Such a proximity would also enable many adults to return to fresh water after spawning.

Elsewhere (Deraniyagala, 1929, p. 31) I have stated that on one occasion a few pelagic elvers of both species were taken together from the waters of the continental shelf, on the Pearl Banks.

It is possible that the elvers of *bicolor* after a long migration met or overtook those of *elphinstonei* which had metamorphosed comparatively close to land, and both were continuing their migration to fresh water together.

The layers of water inhabited by eel larvae are of interest. Some of the specimens taken by Schmidt were in tow nets with 100-300 metres of wire out and the ship moving at 2-3 knots Weber and Beaufort (1916) record three taken in surface tow nets, one in estuarine waters, and five from depths between 1,270-2,477 metres, while the great majority of specimens taken by me were from the surface at night. The earliest capture was 8 P.M. but usually the larvae commenced to appear after 10 P.M. when the ship was anchored close to the edge of the continental shelf.

Generally speaking an Apodal larva is strongly compressed, but its actions, both in and out of water, are typical of the subcylindrical adult. When placed in a jar of water the larva swims nose to bottom

and body nearly vertical in an attempt to descend. If sand is provided it generally burrows into it tail first and remains with the head and about a sixth of the body out of the aperture, swaying to and fro as does the adult, when seen in a cranny in the coral reef. After a while the animal emerges from its burrow keeping the end of its tail inside and swings round, probably in search of food. When deprived of water the larva maintains the dorsiventral position of its body and progresses with the sinuous action of the adult, and if its head is touched is always ready to wriggle backwards tail first, as do adults. In spite of its fragile appearance, an eel larva lives for several minutes, and survives the majority of young fishes taken with it in the dip net. The wriggles of the dying animal as it lies on its side resemble more the passage of peristaltic waves than a genuine wriggle and even in this respect the larva resembles the adult.

As no attempt has yet been made to ascertain the development of Ceylon Apodes the larval forms obtained are described and left unnamed until such time as their specific identity with the adult can definitely be ascertained. Some characters however are noteworthy. It is known that at one stage of their development the larvae of Congroid eels have the cloaca placed far back (Fig. 1). The rostral constriction and nature of the nares in Fig. 5 suggest that this is a *Muraenesox* while the absence of the caudal fin in Fig. 7 places this form as one of the Ophichthyidae Fig. 9 displays some characters of the Moringuidae and the absence of pectorals in the last 2 specimens is a character prevalent among the Muraenidae.

P Deraniyagala del

Fig. 1   Larva I. × 1.1

Larva I

Taken on Pearl Banks. No data.

Length 90 mm., depth 7.5 mm. Cloaca close to end of tail. 103 preanal and 11 postanal segments. Head length[1] 13 into total length or 1 into tail length. Depth of body 11.5 into total length. Head

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[1] *Head length* is measured from tip of snout to gill cleft, *total length* includes the caudal fin when it is present.

compact, snout slightly longer than diameter of orbit. Nares on snout.
Mouth terminal, gape ends under middle of orbit. Teeth strong and
of moderate length, decreasing in size posteriorly, 12 on each upper
and lower jaw. Gill opening small, pectoral rudimentary. Two
branchiostegals recognizable. 40 fin rays on posterior half of tail in
which the fin was damaged.
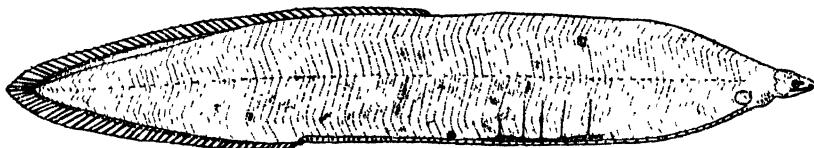
P. Deraniyagala del.

Fig. 2.   Larva II. × 1.6

Larva II

   Taken at night while at anchor on Wadge Bank. May 6, 1926.
   Position 7° 36.6′ N. 77° 58.1′ E. Length 73 mm., depth 12 mm.
68 preanal segments, 42 postanal ones. Head length 11.5 into total
length or 4.3 into tail; depth 6.1. Head rather elongate, snout about
twice length of orbit. Anterior nares short tubes in upper lip close to
tip of snout, posterior ones holes in front of orbit. Gape ends slightly
behind eye. Upper jaw with 4 moderate teeth behind anterior naris.
Gill opening shorter than depth of eye. Pectoral rounded, as large
as eye. Single fins confluent. Origin of dorsal ahead of anal by a
distance equal to depth of body.

P. Deraniyagala del.

Fig. 3.   Larva III. × 1.9

Larva III

   Taken March 3, 1926, with a dip net at surface at 9.15 P.M. Locality
8° 24.5′ N. 79° 39.9′ E. Length 62 mm., depth 9 mm. Cloaca further
from gill cleft than from end of tail. 80 preanal and 80 postanal
segments. Head length 14.5 into total length or 6 in tail. Depth of
body 6.5 into total length or 3 into tail. Head compact with a convex

profile. Snout about twice width ot orbit. Nares anterior to eye. Mouth terminal, gape ends under posterior margin of orbit; 7 teeth on upper and 8 on lower jaw, weaker posteriorly. Gill opening not as long as depth of eye; 5 gill rakers on lower ramus of first branchial arch. Branchiostegals 4. Pectoral somewhat larger than eye. Origin of dorsal above 14th segment and 1½ head lengths behind gill cleft.

Intestinal diverticulum at 22nd segment.
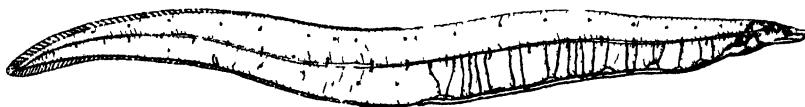
P Deraniyagala del

Fig. 4. Larva IV. × 1.6

Larva IV

Taken March 3, 1926, with a dip net at surface after 10 P.M. Locality 8° 24.5′ N. 79° 39.9′ E. Length 70 mm., depth 7.5 mm., tail slightly longer than head and body.

58 preanal and 76 postanal segments.
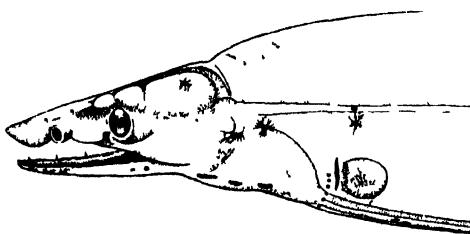
P. Deraniyagala del.

Fig. 5. Head of Larva IV. × 9.5

Head length 12.4 into total length or 6.2 into tail length (inclusive of caudal fin). Depth of body 9.3 into length. Snout conical, elongate, about 4 times orbit length. Both nostrils in lip, anterior one tubate and behind a rostral constriction in anterior half of snout, posterior one small, just anterior to eye and behind a cutaneous flap. Gape subterminal, ends well behind eye. Teeth widely spaced, short, 3 mandibulars on each side. Gill opening as long as depth of orbit. A well-developed, rounded pectoral present.

P Deranivagala del

Fig 6   Larva V × 6

Larva V

Taken in an all-night tow net at surface.   Ship at anchor off Cape Comorin.   November 3, 1925, at 7° 39′ N. 77° 58′ E   99 preanal and 20 postanal segments.   Head length 8 5 into length or 1.5 into tail only, depth of body 11.5 into length.   Eyes missing, probably eaten by isopods when captured   Snout rather slender, about 3 times length of orbit.   Anterior teeth elongate, almost horizontal, 5 on each upper and lower jaw.   Gill opening present, no pectoral.   Tail short.   Origin of dorsal slightly anterior to that of anal

This specimen was about 20 mm. long   As it has disappeared from the Fisheries collection since 1926 when the drawing was made, the linear measurements are not available.

P Deraniyagala del

Fig 7   Larva VI × 1 2

Larva VI.

Taken in a dip net at surface on March 20, 1926, at 10 P M , ship's position 8° 24.5′ No. 79° 41.5′ E.   Length 90 mm , depth 8 mm.

Total number of segments 158, of which 70 are preanal.
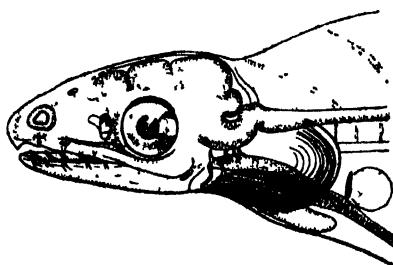
P Deraniyagala del.

Fig. 8. Head of Larva VI. × 11.7

Head is 19 in total length or 8.7 in tail length, depth 11.2. Rather compact head with nares on snout; gape reaches to under hind edge of orbit. 5 short caninoid teeth on each jaw. Branchiostegals 10.

Fins rays developed. Dorsal fin overlaps anal and has its origin closer to snout tip than to cloaca. Anal fin deeper than dorsal. Rays of both fins longer posteriorly than anteriorly. No caudal fin. Pectoral rounded.

This larva belongs to one of the Ophichthid eels, as denoted by the absence of the caudal.
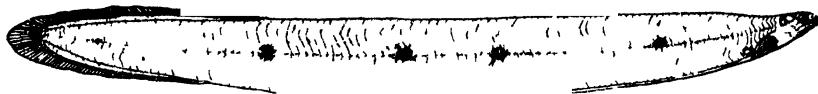
P. Deraniyagala del.

Fig. 9. Larva VII. × 2.4

Larva VII

Two specimens taken on March 3, 1926, with a dip net at the surface. Time 10 P.M. Locality 8° 34.5′ N. 79° 39.9′ E. Length of one (A) 44 mm., depth 4 mm., length of the other (B) 42.5 mm., depth 3.5 mm. (A) has 108 segments of which 70 were preanal; head length contained 10.5 in total length or 3.7 in tail; depth 10.25 in total length or 3.75 in tail (Fig. 9).

(B) has 103 segments. Undershot with the gape ending behind eye, jaws edentulous. Nares on snout, posterior ones close to eye. Length of snout 1.5 times eye diameter. Gill opening small; pectoral rounded, as large as eye. 9 branchiostegal rays faintly visible. Origin of dorsal anterior to anal by a head length. Both fins confined to tail. Pigmentation variable. The larger specimen had 4 stellate melanophores on lateral line of both sides, and one near cloaca, with a vestigial one towards end of tail. The other specimen had 6 on left side, 2 on right, and 1 at cloaca.
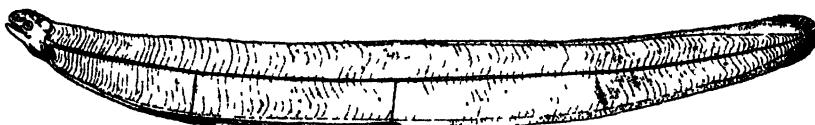
P. Deraniyagala del.

Fig. 10. Larva VIII. × 1.6

Larva VIII

Taken March 3, 1926, with a dip net at the surface. Time 10 P.M. Locality 8° 34.5' N. 79° 39.9' E. Length 66 mm., depth 6.75 mm., tail contained 1.4 in length of head and body. 69 preanal and 53 postanal segments. Head length 13 into total length or 5.6 into tail length; depth 8.9 into total length or 3.9 into tail length. Gape terminal, ending behind eye, jaws edentulous. Nares on snout, posterior ones slightly anterior to upper margin of orbit. Gill-opening small, branchiostegal rays 5. No pectorals. Rays developed on caudal only which is deep, rounded and with 45 rays.
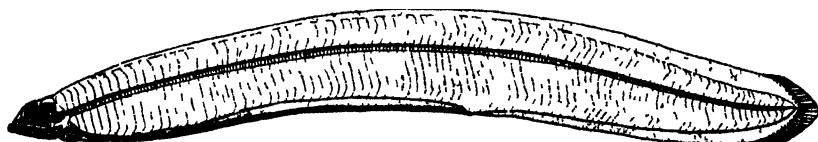
P. Deraniyagala del.

Fig. 11. Larva IX. × 1.6

Larva IX

No data. Length of specimen 69 mm., depth 9 mm. Total number of segments 101, of which 55 are preanal. Head 11.9 into total length, depth 7.5. Head compact, mouth terminal, with the two anterior teeth of both jaws moderately projecting and curved. 6 teeth on upper jaw, 5 on lower. No pectorals. Fin rays on caudal only, which is deep and has 28 rays.

P. E. P. DERANIYAGALA.

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2. Neoteny in Crocodylus porosus

P. Deraniyagala del.

Fig 1.   Fig. 2.

Embryo *Crocodylus* without post-occipitals × 3   Embryo *Crocodylus* with post-occipitals × 3
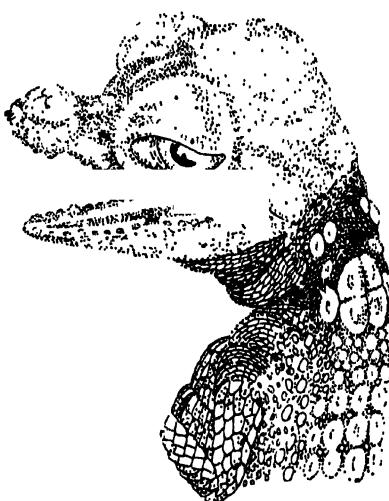
Embryos from brood II

Two generally accepted features distinguish *Crocodylus porosus* Schneider, from other species of the Indian subregion. The first is the comparative absence of post-occipital scutes which appear in an occasional specimen as two small ones. The second is that this crocodile frequents the sea, where in some parts of the world such as the Federated Malay States, it is a danger to fishermen and bathers. It is not entirely marine,[1] however, because, unlike the turtles, which nest on the beach, it usually repairs to estuarine water and builds a mound-like nest of decaying vegetation, either by the margin of a river or in a swamp.

The estuarine crocodile of Ceylon which has hitherto been identified with *porosus* differs from the typical form in two respects, *i.e.*, (*a*) that numerous individuals possess 2, 3 or 4 post-occipital scutes [2] which are often as large as the eye or larger; (*b*) that the animal never voluntarily takes to the sea. On the contrary, so distressed is this crocodile by a marine environment, that when swept down by floods, it generally falls an easy prey to fishermen.

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[1] Dr. A. Herre, late Director of the Philippine Fisheries, informs me that he has often seen *porosus* on reefs in the Sulu sea, 40 miles from land and has noticed specimens on islands which have no ponds of fresh water.

[2] Dr. S. L. Hora informs me that out of the entire collection of *Crocodylus porosus* in the Indian Museum, only one possesses vestigial post-occipitals.

The presence of post-occipital scutes was studied in the following series of estuarine crocodiles : —

I.　Two embryos about 75 mm. in length with a gape length of 14 mm.　One with 2 well-developed post-occipitals, the other with 4. Thirty-six eggs sent by Mr. H. M. D. Soysa from a mound-like nest at Hermont Estate, Gōna-pīnu-vala near Hikkaduva (Southern Province), found on August 24, 1931.　The eggs were 79 to 82 mm. long, 49 to 51 mm. wide and weighed 117 to 120 gm. each.　Embryos were obtained from 2 eggs.

II.　Twenty-two embryos ranging from 75 to 123 mm. in length. The position of their post-occipitals was as follows : One had none (Fig. 1); one had 2 on the left, none on the right; one had 2 on the left, 1 on the right; four had 1 on each side, and fifteen had 2 on each side (Fig. 2).　The mound-like nest containing 46 eggs was found by Mr. F. B. Fernando on Woodland Estate, Gōna-pīnu-vala, on June 20, 1933.　The eggs ranged from 79 by 50 mm. to 84 by 51 mm. and weighed 116 to 120 gm.　The mother, which was on guard, was shot and the skull forwarded together with 32 eggs.　The former agreed with the general description for *porosus*.[1]　(Plate X.)

III.　In contrast to these two sets of embryos with post-occipitals was a brood of 6 newly-hatched young, ranging from 274 to 287 mm. in length, obtained from Puttalam (North-Western Province), in June, 1911.　These displayed no trace of post-occipitals and could be ranked unquestionably as *C.porosus*.

IV.　Length of specimen 380 mm., gape length 55 mm.　Post-occipitals none.　Taken in the Gin ganga (river), Bentota (Southern Province).

V.　Length 400 mm., gape 55 mm.　Post-occipitals none.　From Nil vala ganga (river), Matara (Southern Province).

VI.　Length 400 mm., gape 56 mm.　Post-occipitals 2, vestigial. Locality unknown.

VII.　Length 600 mm., gape 85 mm.　Post-occipitals 2, vestigial. Locality unknown.

VIII.　Length 1,473 mm., gape 170 mm.　Post-occipitals 2, each as large as eye.　Locality unknown.

IX.　Head only.　Gape length 220 mm.　Post-occipitals 2, each slightly smaller than eye.　Taken at Tamblegam lagoon (Eastern Province).

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1 The basal width of the snout was contained 1⅔ times in the length of the snout, while each preorbital ridge extended over about ¼ of the snout length.　The premaxillo-maxillary suture of the palate was produced posteriorly into a U.　The supratemporal foramina were triangular. (Plate X.)

X. Length 2,000 mm., gape 230 mm. Post-occipitals 2, each as large as eye. Locality unknown.

XI. Length 4,300 mm. Post-occipitals 3, each as large as eye; 2 on left, 1 on right. Taken at Handela (Western Province).

XII. Length 4,500 mm., gape 310 mm. Post-occipitals 2, each as large as eye. Taken from Bolgoda lake (Western Province).

XIII. Length 5,410 mm., gape 508 mm. Post-occipitals 4, each as large as eye. Taken at Nākulugamuva lagoon, near Dikvälla (Southern Province).

Hence although the post-occipital scutes were absent from a brood of 6 young, they were present on the majority of the remaining specimens examined.

Only 1 out of 24 embryos,[1] and 2 out of 10 specimens ranging from young to adult, lacked the post-occipitals.

As the nuchals were proportionately larger than the dorsal scutes in the embryo, it appeared probable that the former decreased in size with age. If the post-occipitals also diminished, it appeared quite possible, that at birth these would be vestigial. Such a view was supported by the newly-hatched brood from Puttalam and by the absence of one, or even both, post-occipitals on one side of other estuarine crocodiles. However similar deficiencies occurred even in embryos and as well-developed post-occipital scutes were found on several adults, this view might be only partially, if at all, correct. It is evident that these scutes are common in the adult estuarine crocodiles of Ceylon and denote that either (a) there are 2 subspecies; a palustrine one with, and a fluviatile one without, post-occipital scutes or (b) that the post-occipital scutes of *Crocodylus porosus* persist better in specimens from Ceylon than elsewhere.

In connexion with the first suggestion it is of interest to know that an estuarine crocodile from Ceylon was imperfectly described by Seba in *Thesaurus* Pl. CIII, Fig. 1 as *Crocodilus Ceylonicus* (Kelaart p. 183), while Gray and Günther identified another with *Crocodilus biporcatus* Cuvier, in their list of Ceylon reptiles published by Tennent (1861).

It is also known that in New Guinea, there is besides *C.porosus* another species *C.novae-guineae* Schmidt, which had been classed as *porosus* until 1928. This new species possesses post-occipitals, avoids the sea and is considerably smaller than the former (Schmidt, 1932) whereas Ceylon specimens with post-occipitals appear to show no difference in size from others without these scutes. (See series listed.)

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[1] The dimensions of the eggs, and the constancy of the post-occipital scutes in the embryos, at first suggested *C.siamensis*, a form which possesses preorbital ridges. However *siamensis* like *palustris* does not build nests, but buries its eggs in the sand. (Smith, 1931.)

In considering the second view, the comparatively constant presence of post-occipitals in the embryos from Gōna-pīnu-vala when contrasted with their absence from the newly-hatched young of Puttalam, suggests that the two characters are mendelian allelomorphs.

In conclusion it is probable that, in Ceylon, there is only a single estuarine species which is a neotenic form of *C.porosus*. The nesting habits of the typical form would seem to denote that its marine habit is a comparatively recent development. It is also known that all other crocodiles possess post-occipital scutes. Hence it is reasonable to suppose that at one time the ancestors of *porosus* were similarly furnished and did not take to the sea.

The fact that both in New Guinea and in Ceylon, crocodiles regarded as *porosus* which do not go to sea retain their post-occipitals suggests, that the disappearance of these scutes is correlated with the development of the marine habit.[1]

Examination of further embryonic material is necessary before the specific status of the estuarine crocodiles of Ceylon can be definitely ascertained, but the two features which called for such an investigation at present appear to be neotenic characters of *Crocodylus porosus* Schneider.

<div style="text-align:right">P. E. P. DERANIYAGALA.</div>

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EXPLANATION OF PLATE

PLATE X

Skull of mother of brood II

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[1] Several extinct crocodiles, *e.g.*, the Thalattosuchia, display degeneration and even complete loss of the osteoderms. A similar process has probably commenced in *C.porosus*, for the osteoderms of this species are no longer contiguous, as in other living crocodiles.
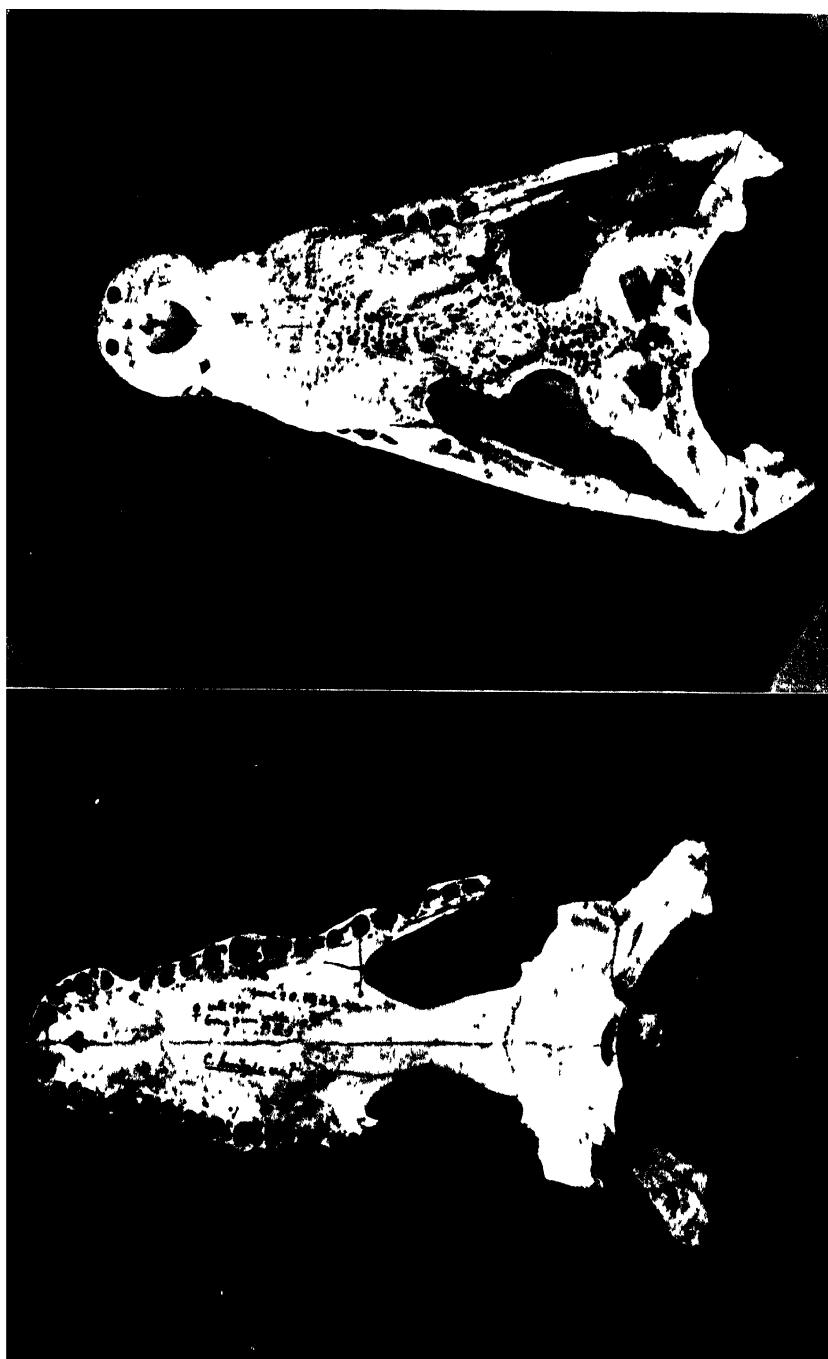
The Geology of Ceylon

BY

J. S. COATES, B.A. (Cantab.)

(*Late Government Mineralogist and Salt Adviser*)

(With Twelve Plates, Seven Text Figures and one Map)

Most of the field work from which this outline of the Geology of
Ceylon is prepared was done by the author while employed as Mineral-
ogist to the Ceylon Government. A number of scattered observations
were made while the work which was of a purely economic nature was
being carried out. These have been linked up in the last three years
by necessarily rather rapid traverses over the greater part of the Island.

Some field work has been done in recent years in the Island by
A. K. Coomaraswamy, J. Parsons, and J. A. Daniel, while employed
under the Ceylon Government on the Mineral Survey of the Island,
but the records of the work of the last two named are scanty. Papers
by Coomaraswamy in various scientific journals are quoted in the text.
The observations of J. Parkinson on Ceylon rocks studied during a
short visit to Ceylon were also published in the *Quarterly Journal of the
Geological Society*. The author of this paper had the assistance of
E. J. Wayland, now Director of the Geological Survey of Uganda,
for five years. His work on the young sedimentary rocks of the north-
west coast was published in the *Quarterly Journal of the Geological
Society*, and on the Jurassic rocks of Tabbowa in *Spolia Zeylanica*.

Dr. F. D. Adams of Toronto University made some rapid tours in
Ceylon in 1924 and the following years, and published a monograph on
the Geology of Ceylon in the *Canadian Journal of Research* in which
his observations were embodied.

Other references to the geology and petrology of Ceylon are contained
in various journals, a bibliography of which is included in Adams'
paper.

No geological survey of Ceylon has yet been undertaken and the time available to the author of this paper and his predecessors did not permit of the accurate mapping of the boundaries of the formations recognized. The limits of the formations as shown on the map are therefore not to be taken as definite.

Spelling of Place-Names

All names of places, hills, &c., are spelt in the same way as on the Survey Maps of Ceylon issued by the Surveyor-General.

References to Publications

The following abbreviations are used in this paper:—

S. Z.—*Spolia Zeylanica.*
Q. J. G. S.—*Quarterly Journal of the Geological Society of London.*
R. G. S. I.—*Records of the Geological Survey of India.*
M. G. S. I.—*Memoirs of the Geological Survey of India.*
C. J. S.—*Ceylon Journal of Science.*

Reference is also made to The Geology of Ceylon by Dr. F. D. Adams, reprinted from the *Canadian Journal of Research* 1929, under the author's name.

GENERAL OUTLINE

Roughly speaking nine-tenths of the Island are occupied by Archaean crystalline rocks, with only narrow belts of sediments along the coast. The sequence of formations as determined by the author is as follows:—

Post tertiary—River alluvium (including gem gravels), coastal deposits (lagoon, estuarine, and sea beaches).
Miocene—*Kudremalai, Minihagalkanda,* and *Jaffna* rocks.
Jurassic—*Tabbowa* series.
Archaean

1. Younger pegmatites.
    Dolerite dykes.
2. *Wanni gneiss* of north and north-west.
3. *Charnockite* series.
4. *Khondalite* series.
5. ·Older biotite gneiss (*Bintenne gneiss*).

The sedimentary rocks of the Island will be dealt with first, and the crystalline rocks later.

POST-ARCHAEAN ROCKS

Jurassic

Tabbowa Series

The rocks of this area were examined by E. J. Wayland and his observations and deductions were published in the *Ceylon Journal of Science*, Section B, Volume XIII, pp. 195-208. His conclusions are here summarized.

The Tabbowa beds occupy an area of less than a square mile to the north and east of the Tabbowa tank, crossing the Puttalam-Anuradhapura road between 7½ and 9 miles north-east of Puttalam. They comprise conglomerates, grits, sandstones, argillaceous sandstones, shales, and nodular limestones. The beds were well exposed in excavations for irrigation work at Tabbowa. Low escarpments of sandstones are traceable through the jungle and exposures along the stream beds are fairly frequent. The sandstones consist of coarse angular quartz grains with abundant felspar and some mica, the natural constituents of a sediment formed from the detritus of the neighbouring granitoid rocks. They show jointing along NNW-SSE planes, parallel to the dominant strike of crystalline rocks in the western part of Ceylon. Alternating with the sandstones are coarse grits. These coarse arenaceous rocks are the basement beds of the series, resting on a decomposed crystalline rock floor. They are succeeded by brown shaly beds with inconstant bands of nodular limestones, and pass upwards through alternations of arenaceous and argillaceous beds to massive grits and sandstones which form prominent surface features.

The Tabbowa beds occupy a syncline faulted into the crystalline rocks. The thickness is estimated at over 2,000 feet, but this figure is quoted with reservations and the evidence in support of it is slight.

The sandstones and shales are unfossiliferous but a thick bed of pipe clay yielded a number of plant relics in the form of impressions. A list of the fossils identified is contained in a paper by Seward & Holttum and quoted by Wayland. The authors conclude that the majority of the species identified correspond to plants recorded from the Madras coast, and are of Jurassic age, probably lower Oolite and Upper Liassic, and that the beds belong to a southerly extension of the Kota Series, at

the top of the middle group of the Gondwana System. Wayland tentatively suggests that they were laid down as fresh-water deposits in one of the numerous fault-troughs formed during the break-up of Gondwana-land.

Miocene

Minihagalkanda-Kudremalai-Jaffna Series

The area occupied by these sedimentary rocks was carefully examined to determine the possibility of the occurrence of petroleum. The field work was done entirely by E. J. Wayland, and a paper on the Miocene of Ceylon was published by him in collaboration with A. M. Davies. (*Q. J. G. S.* Vol. LXXIX., pp. 577-602.)

The rocks occur in two widely separated areas. The Kudremalai-Jaffna series extends from the neighbourhood of Puttalam as a coastal band gradually increasing in width to the north and covering the whole of the Jaffna peninsula. The inland boundary is not determinable. At the southern end it probably runs roughly parallel with the coast about ten miles inland. East of this is a chain of outcrops of crystalline rocks. Near the mouth of the Arivi river the younger sediments have been eroded away and their surface covered with alluvium. The crystalline rocks appear as far west as Madhu Road Station on the Mannar line. North of this the boundary is uncertain, but it does not extend as far south as shown in the map on page 578 of Wayland's paper and probably lies in fact only a few miles south of the edge of the Elephant Pass lagoon. Crystalline rocks are seen to the north of Mankulam and along the Mankulam-Mullaittivu road.

The Minihagalkanda outlier lies about 40 miles to the east of Hambantota. It forms a quite narrow belt beginning about 5 miles to the east of the mouth of the Yala river and extending for 2 miles along the coast from near the Pilinawa inlet to Udapotana. On the seaward side the rocks are exposed in a low cliff. The high land extends inland for about a quarter of a mile and then descends steeply to plains covered with recent alluvium, through which the level surface of the underlying gneissose rocks appears occasionally at about sea-level.

A third exposure of sedimentary sandstone was reported by Wayland near Weligama. This however is a recent sandstone, similar in origin to the sand-reefs of the coast, and has no relation to the other rocks described.

In the north-western area a limestone bed is exposed at intervals from the latitude of Kalpitiya to the extreme north of the island. The more southern exposures are generally flat surfaces not much above sea-level, though the outcrop seen in the Moderagam river near the ancient stone dam, may be nearly 50 feet above sea-level, and at Kolankanatta, 6 miles south of Kudremalai, they form a sea-cliff of about the same height. In the outlying islands the limestones again appear as flat beds with a scanty covering of soil, almost at sea-level. In the Jaffna peninsula on the contrary the limestone forms an extensive tract with an area of over 200 square miles rising to 50 feet above sea-level at Kirimalai, where its northern edge forms a sea-cliff.

The limestone, which is fossiliferous, is succeeded by a series of areno-argillaceous beds, generally mottled sandstones, probably uncomformable, and well exposed between Kudremalai and Arippu. Another series of sandy beds is found south of Kudremalai. This includes a bed of nodular limestone and is capped by a dark red sandstone. Fossils from a false-bedded sandstone near the base were indeterminable.

The fossils from the Jaffna limestone included several identifiable species of molluscs and foraminifera. They have been studied in detail by Dr. A M. Davies, who concludes that the Minihagalkanda beds of the south-east are probably of Tortonian age, while the Puttalam-Jaffna limestones may be as late as Pontian or Sahelian. The palaeontological evidence also leads to the conclusion that the rocks of the north-west of Ceylon are identical with similar rocks at Quilon in Travancore, and are of older date than those of Karikal on the Coromandel coast of India.

The areno-argillaceous beds are exposed along the coast from Marichchukkaddi to near the mouth of Arivi river, forming a small cliff about 10 feet in height and extending inland as a level plain. At Kudremalai they are capped by arenaceous beds, the upper one being a dark red sandstone. A narrow ridge of the same rocks extends along the shore of the mainland nearly as far south as Karaitivu, opposite Kalpitiya, at the mouth of the Puttalam lagoon. The summit of the ridge rises to 225 feet at Kudremalai and 260 feet at Aruakallu. Its width is not more than a mile at the maximum and on the landward side it sinks rapidly to much lower plains. The ridge therefore has a morphological resemblance to the narrow belt of Miocene rocks at Minihagalkanda.
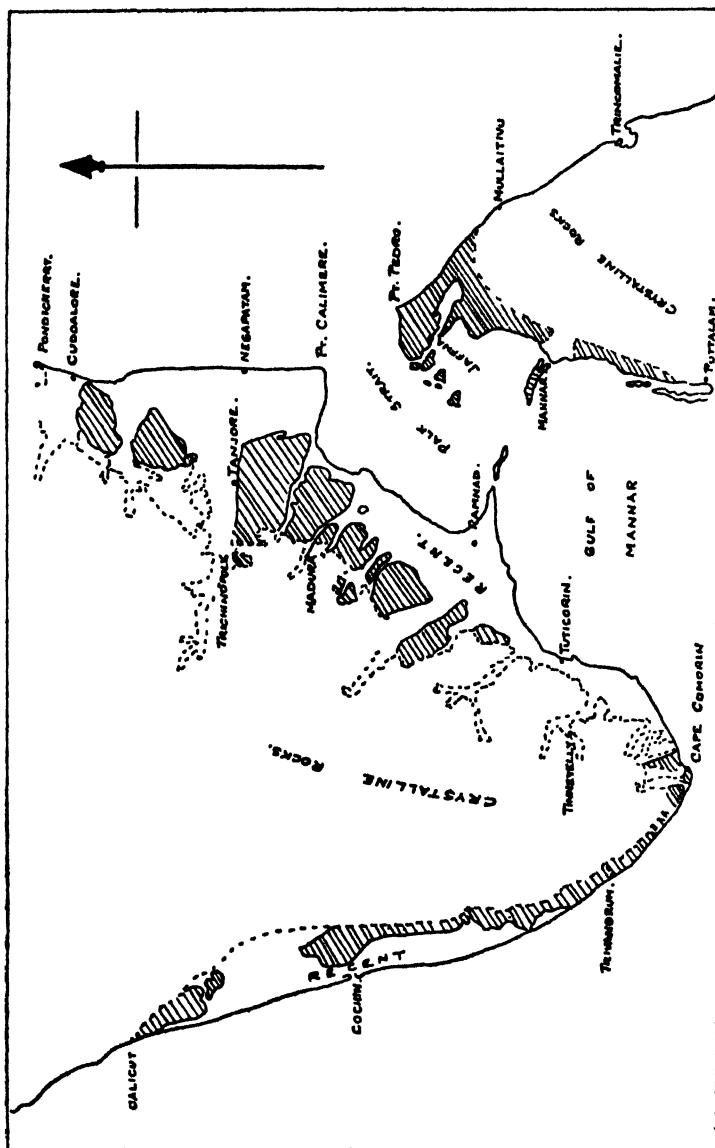
Fig. 1. Distribution of Tertiary rocks in North Ceylon and South Indian (partly reproduced from Geological Survey Map of India 1931).

The beds contain some unidentifiable fossils, which seem to point to a Kainozoic age. They agree very closely in lithological characters with the Warkalli beds of the Travancore coast, which also are considered to be a fresh-water formation.

The sketch map facing this page shows the area occupied by these rocks in northern Ceylon and their distribution in South India as shown by the Indian Geological Survey map of 1931.

Pleistocene and Recent

Coastal Deposits

Nearly the whole coast-line of the island is fringed by deposits of marine sand in the form of beaches or sand bars and spits. The beach-deposits increase in width from the south-western corner of the island in both directions, attaining their maximum width on the west coast near Chilaw and on the east coast near Kalkudah.

The sand bars and spits enclose lagoons, which show a striking difference in type along different sections of the coast. Along the south-west coast from Matara to Galle and Colombo they are typical drowned valley-systems cut off from the open water by sand-bars, and characteristic of a submerged coast-line. From Colombo northward on the other hand the marine deposits take the form of narrow spits, up to 25 miles in length, connected with the land at the southern end and enclosing wide lagoons, the inner shore of which is low and sandy, with an even trend parallel to that of the spit. Such sand-spits and lagoons are characteristic of stationary or emerging shore-lines.

At first sight therefore it would appear that the coastal belt south of Colombo has undergone submergence, while north of Colombo it is stationary or emergent. The difference in character is due to a difference in the conditions of accumulation of the detritus supplied by the land. The charts show a steady diminution of the grade of the sea-bottom northwards from Galle. Somerville (*S. Z.*, Vol. Y, Pt. 18) conjectures from observations made at a depth of 10 fathoms during a survey of the coast that there is a steady current northward along the sea-bottom and records that off Mt. Lavinia there was a complete absence of loose material on the rocky sea floor.

It is also noteworthy that along the south-west coast the hills approach nearest to the sea and often run out to sea in promontories terminating in cliffs. This section of the coast is exposed to the full force of the waves in the south-west monsoon and its form shows that it is being rapidly eroded. It appears therefore that there is a constant transfer of coarse material from this part of the coast, and of
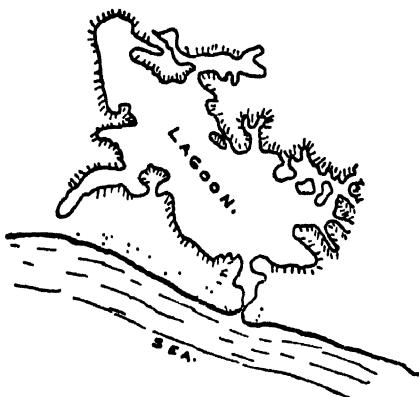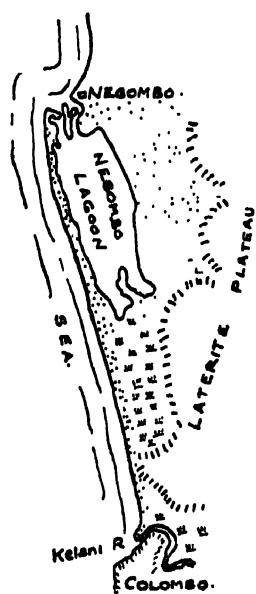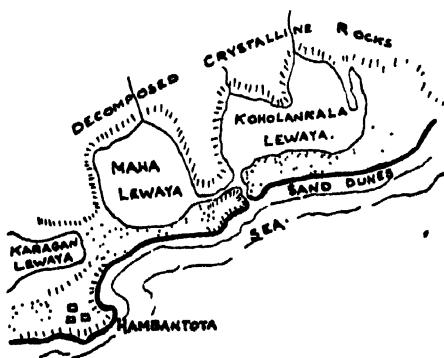
Fig. 2. Typical Ceylon Lagoons.

finer material brought down by the rivers, from south to north. Near Colombo, the detritus begins to settle down, all of it being eventually deposited in the Gulf of Mannar.

The old shore-line, as it lay when the depression which formed the bays of the south-west coast had ceased, cannot be traced accurately north of Colombo, but it is evident that it lay several miles inland from the present shore behind the wide extent of sandy and clayey lagoon deposits near Chilaw. I conclude therefore that the change in character of the coast that occurs near Colombo is due to the gradual weakening of the bottom current, and that north of Colombo the rapid accumulation of detritus has overcome the effect of submergence of the coast and allowed the formation of sand-spits and lagoons of the Negombo type.

The pro-grading of the shore-line is still more rapid in the bight between Colombo and the mainland north of the Mannar peninsula. Along the Ceylon coast a succession of four or five beach-bars, separated by marshy flats, can sometimes be made out. The older bars inland are wider and higher than the younger and covered with denser vegetation. The last bar formed along the shore supports only grasses or thorn-bush. New off-shore bars or spits are in places emerging from the water.

The lagoons of the east coast are not so completely typical in form as those of the west. They are equally extensive though in large part silted up. The rivers of this side of the island are subject to rapid floods and bring down a heavy load of detritus to the sea. The accumulation of marine sand is however in part due to the landward counter-current along the bottom set up by the strong off-shore wind that prevails during the south-west monsoon. There is direct evidence along this coast of the pro-grading of the shore-line in the existence a mile or two inland of a fringe of rounded pebbles around the base of rocky hills that now protrude from the sandy and clayey flats.

The Hambantota lagoons (lewayas) require special notice. Their structure has been carefully studied in connection with the salt deposits that form in them. The lagoons are irregular basins bounded on the land side by low bluffs of decomposed gneissic rocks, and on the sea-side in part by elevated bands of decomposed rock, but mainly by wide beach-bars capped by blown sand. There is generally one well-defined mouth from which flood water escapes. This is closed by a sand bar immediately the outrush of water has ceased, but in rough weather the waves shoot over the bar and a certain amount of sea water enters the lagoon.

The structure of the lagoons is shown in the generalized diagram F'g. 3). From the surface to within a foot or two of the crystalline rock floor they are filled with a very tough calcareous clay, which is quite impervious to water. Below this is a thin pervious sandy layer resting on a few inches of sandy clay which represents the more highly decomposed surface of the bed-rock. The impervious crystalline rock floor is mainly flat and lies about 30 feet below sea-level. On the seaward side it may rise to about sea-level and remain exposed or become capped by sand-dunes. Over large stretches of the perimeter however, the rock-floor after rising gently sinks again under the bed of the sea and never reaches sea-level. Along these portions of the perimeter the only barrier against ingress of the sea is a porous beach sand which extends to below sea-level and is capped by dunes. At high water the level of the open sea is above that of the lagoon floor and the pervious sand affords a passage to sea water. Sea water may be observed to enter the lagoon by this passage, in addition to that which finds its way over the lowest part of the sand-bars in rough weather.
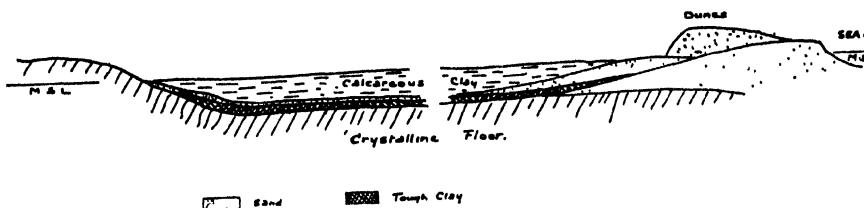
Fig. 3. A generalized diagram of a section across a typical lagoon.

The structure of the lagoons, then, corresponds with that 'of the Larnaca Salt Lake in Cyprus, described by Bellamy (*Q. J. G. S.* Vol. LVI, pp. 745-758, 1900). The Larnaca lake however lies several feet below sea-level and the amount of sea water entering it by seepage is much greater.

In ordinary seasons salt separates from the concentrated brine in the Hambantota lagoons at the end of the south-west monsoon. Most of it is collected for domestic use, and any surplus is dissolved by the rains of the other monsoon, which frequently breach the mouth of the lagoon and carry the dissolved salt back to the sea. The gypsum separated from the sea brine during evaporation, however, is partly left behind as rosette-shaped groups of crystals which are fairly plentiful in the upper layers of the lagoon clay.

Patches of shell-bearing clayey beds are found at intervals along the rim of the Hambantota lagoons and at many other places on the

south-east coast. The shells all belong to existing species. The sur-
face of the beds is from 12 to 20 feet above the present sea-level.
Brackish water deposits of this nature could not have been formed
in lagoons behind a barrier rising to nearly 20 feet above sea-level
unless the climate of the region had been different from that of the
present day. The drainage basin of some of the Hambantota lagoons
is extensive and the flood water of the rainy season would suffice to
break through any barrier that might have been formed. It may
therefore be taken that these beds indicate an elevation of somewhere
about 20 feet in this region, preceding the depression which originated
the existing lewayas.

Coastal Sandstone

A very conspicuous feature of the western shore of Ceylon is a band
of coarse to fine sandstone which is exposed at low water mark along
the toe of the sand beach-slope. The rock is composed of quartz
grains and shell fragments with a calcareous cement and frequently
encloses parallel bands of ilmenite and garnet grains. These heavy
mineral bands may increase in width till the sandstone becomes an
ilmenite-rock. When the dark and light bands alternate the sandstone
has at first glance the appearance of a banded gneiss.

The sandstone has apparently a gentle seaward dip. This however
is due to false bedding. The coarse and fine quartz grains and the
bands of ilmenite and garnet have exactly the disposition of the
minerals on the existing beaches. The streaks of ilmenite correspond
with those formed by wave-action to-day. In any section of the beach
these may be seen to alternate with bands of quartz sand. The
sandstone is quite clearly a cemented beach deposit.

Similar ' stone-reefs ' have been described by Branner (The Stone
Reefs on the north-east coast of Brazil. *Bulletin Geological Society
America*, Vol. XVI, pp. 1-12, 1905) as fringing the coast of Brazil for a
distance of 1,250 miles. Like the coastal sandstone of Ceylon they
underlie sand-spits enclosing lagoons. Branner ascribes their formation
to the action of water charged with organic acids which percolates from
the lagoons. In contact with the shelly sand of the spit calcium
carbonate is dissolved by the organic acids of the lagoon water. Where
this lime-charged water meets the sea water lime is precipitated between
the grains of sand, cementing them to a hard rock. In Branner's
opinion a high density of the sea water is essential.

The Ceylon stone reefs occur, with a few exceptions, under precisely
similar conditions. They are all to be found on the edge of lagoons

enclosed by sand-spits, though in some places widening of the spit by accumulation of sand and choking up of the lagoons tends to conceal their original relations. One of the most conspicuous outcrops is the Pamunugama reef, which fringes the shore almost the whole way from the mouth of the Kelani river to the headland off Negombo and runs out to sea for a short distance beyond it. The reef emerges from below the narrow sand-spit which encloses the Negombo lagoon and the swampy Mutturajawella south of it, which is a silted-up portion of the old lagoon.

Some of the reefs start from the shore-line and run at a small angle out to sea. A striking example of this is the Tirukkovil reef, which starts from near the old resthouse site at Tirukkovil on the east coast, and runs out to sea for over 2 miles at a slight angle with the coast.

In a few places similar sandstone beds may be seen a short distance inland, but still under a portion of an extensive sand-spit. The lagoon mouths between Kalmunai and Batticaloa are crossed by causeways built on a sandstone bar of this nature, which does not extend to the present shore-line. A similar bar is seen north of Mullaitivu. In rare instances the reef may be exposed on the inner side of a spit, as at Chilaw. A sandstone reef here extends along the shore from some miles south of the town and continues under the spit north of the town for 2 miles, nearly to the mouth of the Deduru river. The inner edge of the reef has been exposed by the scour of flood water.

Accepting Branner's view of the mode of origin of these stone-reefs, their degree of exposure is an index of the movements of the shore-line. Cementation of the sand of a spit can hardly take place on the face of a beach exposed to heavy scour. On the other hand the cemented stone-reefs show very clearly the concentration of heavy minerals in bands, such as are formed on existing beaches. The reef must therefore have been formed under a bar or spit while it was extending seaward. Where the reefs are now exposed along the shore they indicate retrogression of the shore-line. On the east coast at Kalmunai and Mullaitivu on the other hand, where they are exposed half a mile inland the shore must be pro-grading or stationary.

On the coast of Brazil numerous completely detached stone-reefs are found. On Branner's theory these cannot have been formed under off-shore bars, because there would be no percolating lime-charged water to effect the cementation. They must be detached remnants of long-shore spits. No similar detached reefs are seen on the Ceylon coast, but in some of the exposures described the reef is tied to the land at one end only and may eventually be altogether detached.

While these consolidated sand-bars act in most places as a protect-
ive barrier against erosion, they may, when partially detached from
the shore, have the opposite effect. A detached reef presents a gently
sloping surface to the waves which break and run over it into the
basin between the reef and the shore. The tendency is therefore
to raise the water-level inside to above the normal, and to set up a
constant current through the gap between the end of the reef and
the shore, with consequent strong erosion at this point. This erosive
action may be watched at the north end of the Pamunugama-Negombo
spit. At Tirukkovil strong erosion of the coast inside the sandstone
reef was going on when I last visited the spot in 1927. It is probable
that some of the violent accentuations of coast-erosion which occur
periodically on the south-west coast are due to the breaching of an
outer barrier of this nature.

Shore Deposits of Coral

A deposit of coral debris extends along the south-west coast from
Ambalangoda to Matara. It consists of coral of many different kinds
mixed with fine sand and shell-fragments. At Akurala, where it is
most extensive, the deposit extends inland for 1,000 yards from the
shore to the edge of a low plateau of decomposed crystalline rocks.
The area is covered by swamp vegetation and is cut off from the
sea by a sand-bar. The depth of the coral is about twenty feet : it rests
on decomposed gneiss. Much of the material has been dug for lime-
burning. South of this the coral belt is not so wide, and it is in-
terrupted where the hard rocks run down to the sea. No coral is
found in the beds of the actual lagoons, except for a small deposit in
the Madampe lake.

Somerville (*S. Z.*, Vol. V, Pt. 18) regards the deposit as an old
reef. It appears to me to be an accumulation of debris washed off
outlying reefs by storm-waves, and similar to the accumulations of coral
seen at Foul Point, Trincomalie, and elsewhere, which are evidently
storm-beaches. During the period of submergence of the coastal belt
bars were formed across the mouths of certain of the drowned valleys,
transforming them into lagoons which have persisted to the present
day. Where the drowned area was not thus protected corals were
driven up to the new shore-line by storm-waves, forming the deposit
which now fringes the old coast-line between the lagoons.

Storm-beaches of coral debris have also been formed on parts of
the coast of the Jaffna peninsula and of some of the detached islands.
These accumulations of coral have frequently formed a rim raised
above the level of the limestone flat inland.

Blown Sand

Sand-dunes are found along most of the coast of the island except the south-west portion. The crescent-shaped Mannar island, which has a length of 16 miles and a maximum breadth of 4 miles, is almost entirely covered by blown sand. The dunes form a series of curved ridges with the concavity towards the south-west. They probably rest on a spit formed by the Arivi river, which reaches the sea a few miles further south. The coast between the mouth of the river and the landward end of the Mannar island is fringed with newly-formed off-shore bars. The Kalpentyn peninsula, south of the Jaffna lagoon, is 10 miles long and presents the same curved form. Both of these spits present a concave surface to the south-west monsoon wind, which blows with greatly increased force in the gap between Ceylon and the mainland of India. On the mainland shore the dunes are very much more extensive.

Dunes are also widely developed along the north-east coast, reaching their maximum width of 2 miles just south of Point Pedro and tapering southwards. They extend as far as the eastern end of the Elephant Pass lagoon and begin again just south of the sand-bar which closes it. The whole of this coast-line from Mullaitivu to Point Pedro is practically a tombolo over 50 miles in length connecting the mainland with the elevated limestone platform of the Jaffna peninsula. The source of all this great accumulation of blown sand is doubtful. According to Somerville the current here runs to the south during the north-east monsoon and to the north during the south-west monsoon. The south-west monsoon along this stretch of the coast is an off-shore wind and blows strongly. It must therefore induce a circulation tending to bring the sand of the sea-bottom towards the shore. The south-west monsoon current would thus tend to wash up on the beach an accumulation of sand which the other monsoon wind transports inland.

An older series of dunes also exists on parts of the west coast and especially along the eastern shore of the lagoons. The sand of which they are formed is, near the surface, red in colour owing to a thin coating of iron-oxide. At depth, and especially below permanent water-level, the sand is white. The coloration is due to the upward migration of rain-water charged with iron-oxide dissolved from the lower layers of sand.

A nearly continuous belt of such dunes extends from Battulu Oya to Puttalam, along the eastern margin of the chain of lagoons. They must have originated soon after the formation of the spit, which

enclosed the lagoons, before any deposit of clayey alluvium had taken place. The south-west wind drives the water out of these lagoons, leaving large areas of the bed quite dry. The conditions are thus favourable for the formation of dunes on the lee-shore.

A similar belt of red dune sands borders the Jaffna-Elephant Pass lagoon on the north. This belt runs in a curve which converges eastward towards the line of Point Pedro dunes on the eastern coast. A long narrow strip of low ground a little above sea-level divides the two dune-belts. The old dunes are stationary, the supply of sand for their extension being now cut off, and they are covered with dense scrub. The outer dunes are however steadily advancing inland. They present the usual steep face on the lee-side—in this case the south-west side—overhanging the Champianpattu lagoon, which eventually must be obliterated.

On the lee-shores of some of the lagoons beds of wind-blown clayey material are also formed. They are well developed on the northern shore of the Elephant Pass lagoon. This lagoon receives the drainage of a number of streams and is filled almost to sea-level with fine clayey silt, which is exposed over large areas at low-water. The clay particles and fine sand when dry are blown inland and form low dunes. In the rainy weather the clay is washed off the surface of these where they are not covered with vegetation, leaving a coating of fine white sand overlying the sandy clay.

<center>ARCHAEAN ROCKS</center>

Bintenne Gneisses

A geographically well-defined group of gneisses occupies the low-country in the south-east of the island, from the coast to the southern and eastern escarpments of the hill country. This area is mainly undulating country with isolated rocky hills and ranges rising up to 500 feet above sea-level, except in part of the Batticaloa District where the peaks rise to over 2,000 feet and the average level is higher than elsewhere. The geology of the area has not been closely studied and few traverses have been made except along the roads. Rock outcrops are certainly numerous throughout but the bare surfaces are invariably deeply weathered. Detached blocks, unless they are of large size, are generally weathered right through, and on a rapid traverse along a line where no fresh rock faces can be studied the information that can be collected is scanty. Weathering of a quartzose rock certainly brings out the foliation but it completely obscures the original nature of felspars and ferromagnesian minerals. Closer study

will no doubt make it possible to subdivide the rocks into distinct groups. For the present they are all included under the name Bintenne gneisses from the name of the area in which they can be best studied.

The predominant rock in the Bintenne country between the hills and the sea-board at Batticaloa is a well banded black and white gneiss with bands of clear quartz and white felspar, separated by finely granular quartz and felspar with abundant dark biotite in irregularly oriented flakes which are not noticeably parallel to the banding. The white bands are composed of quartz in long drawn out, individuals and an intergrowth of larger orthoclase and oligoclase of about the same dimensions, the interspaces being filled with a granular intergrowth of orthoclase-microperthite and microcline.

In the micaceous bands biotite flakes are scattered irregularly through a fine-grained felspathic ground mass in which plagioclase predominates and quartz is relatively rare. Iron-ores are conspicuous in these bands but are not confined to them. Magnetite, sometimes in good octahedra, and zircon in minute prisms, are also common in the light bands. Calcite and epidote are sometimes seen in the neighbourhood of altered plagioclase. On the whole however the rocks are remarkably fresh.

Around Hambantota, at the other end of the region, the rock has the same conspicuous black and white banding but the acid bands are composed almost entirely of quartz and microcline with subordinate orthoclase.

The felspathic bands are sometimes quite coarsely crystalline and the felspars may be crushed and elongated into ' augen '. The rock has then the appearance of a composite gneiss formed by lit-par-lit injections of pegmatite into a pre-existing basic rock. This composite structure may be on a large scale, the pegmatites forming bands which may be several feet thick and enveloping large blocks of a fine-grained micaceous rock. This may be seen in quarries and coastal exposures near Hambantota, and in the small cliff below the resthouse, where however the rocks are all too highly decomposed for identification.

Besides the coarsely banded varieties there are numerous fine-grained greyish white rocks in which no banding can be seen, though the foliation is marked by parallel arrangement of the mica flakes. The proportion of mica is generally small but may increase till the rock has a nearly black colour. The more acid kinds resemble the Ritigala gneisses (p. 162) in the north-central part of the Island.

The accessory minerals obtained by concentration of the crushed rocks, and more or less conspicuous in hand specimens, are magnetite

and ilmenite with minute zircons and a trace of monazite. In the Batticaloa area ilmenite replaces magnetite and sphene is sometimes abundant. Garnet is rare in the type rock, but in some members of the group it is fairly plentiful, and in a band of acid granulite from near Ekiriyankumbura it forms a considerable proportion of the rock in groups of fine rounded grains.

The typical biotite gneiss appears to form the Nuwaragala group of hills east of the main road at Maha Oya, but for the reasons already stated this is not certain. On Nuwaragala it is nearly flat and this gives the characteristic outline to this mountain and others of the group. The dips are everywhere gentle and undulating. The same rock has a wide extension in the plains north of Hambantota. Between these two areas a number of different types are to be seen.

The Moneragala hills which rise to 5,000 feet are separated by a few miles from the main escarpment. They are largely formed of a great lenticular mass of porphyritic granitoid gneiss several hundred feet thick, which thins out into a band of augen gneiss. Similar rocks are found in the Okkampitiya range on the west, and along the Arugam bay road to the east of Moneragala. The granite is coarse, buff-coloured and rich in biotite.

Bands of a rather coarse buff-coloured granulite with strings of orthoclase, partly crushed into augen, are found at various places in the area, e.g., near Ekiriyankumbura near the garnetiferous granulite mentioned above, and at the Gal Oya anicut, 30 miles to the east of the former locality. The latter seems to belong to an extensive band which can be traced southwards for 20 miles to the Arugam bay road. These rocks bear some resemblance to the Ambanpitiya gneisses. They are rich in magnetite: the Gal Oya specimen for example contains enough magnetite to affect a compass needle.

Along the coast a pink gneiss, poor in biotite, is seen between Kirinde and Komari and appears again in the Batticaloa lake. It differs from the typical gneiss of the region in the pink coloration of the felspars and the irregular banding. The quartz-felspar aggregates have a wedge-shaped form and are bounded by selvedges of biotite. The material between them is finely granular. The accessory minerals are magnetite and ilmenite with a trace of monazite.

Along the southern flank of the Kataragam hills there is a wide band of limestone, in part very coarse pure calcite but mainly dolomitic and impure, with the usual accessory minerals. This is associated with highly garnetiferous granulites, some of them coarse with conspicuous

quartz lenticles and bands of crushed garnets, the others very fine-grained, and with hornblendic and pyroxenic rocks closely resembling charnockite in the hand specimen, and showing some hypersthene under the microscope. The rocks have little resemblance to the other members of the Bintenne gneiss group and have rather the appearance of belonging to an outlier of the charnockite-khondalite series.

The gneisses of the Bintenne group appear everywhere along the foot of the escarpment which extends from near Mahawalatenne to Wellawaya. The boundary then swings round to the north and lies somewhere between the Muppane-Bibile road and the main road from Passara to Bibile. At Bibile it bends round the north end of the Madulsima range into the Mahaweli ganga valley and follows the river along its south to north course as far as Polonnaruwa. The northern boundary of the group is doubtful. At Kalkudah and Katiraveli on the coast pink gneisses with monazite as a prominent accessory mineral are found. These evidently belong to the younger Wanni group. The country between the Polonnaruwa-Batticaloa railway and the main Trincomalee road has not been examined. The boundary has provisionally been taken as running between Kalkudah and Kantalai.

At the other end of the belt the biotite-gneisses continue as far as the Walawe ganga valley but are not frequently seen to the west of it. A band of limestone extends for some distance along the Madampe-Liyangahatote road to Timbolketiya and isolated outcrops of this rocks carry the line on to within a few miles of the coast. Charnockite also appears at intervals along this road, but no other members of the charnockite-khondalite group have been seen. Further to the west charnockite is strongly developed. The biotite gneisses have been shown as bounded here by a tongue of the khondalite rocks, but this is hardly more than a surmise.

The strike of the gneisses in the main area is very variable. Near the border of the hill-country the strike is invariably conformable to that of the schists and charnockites. The gneissic bands everywhere dip under the schists, towards the centre of the mountain mass. At a very short distance from the escarpment the dips are much steeper than those of the schists, nearly vertical in fact. Continuing away from the escarpment the dip decreases and becomes flat and undulating, with variable strike. At Batticaloa the average strike is about E-W: going northwards it swings round gradually to NE-SW to conform again with the strike of the khondalite-charnockite series. The strike only settles down, however, at the line where reddish gneisses of the Wanni type begin to be conspicuous.

Other Areas

Biotite-gneisses of similar type occur in many localities outside the area described. The most extensive development is seen on the north-west side of the long belt of khondalite-charnockite which extends from the central mountains to the sea at Trincomalie. They are well seen in the Dambulla rock and at Habarane, and as far to the north-west as Kekirawa, where gneisses of the Wanni type become predominant. The band of biotite gneiss tapers out to the south and is replaced by a band of hornblende gneisses of a special type (Kadugannawa gneisses) which borders the schistose series from Matale to Kadugannawa.

Another well-marked band of greyish biotite-gneisses begins beyond the belt of Kadugannawa gneiss and continues through the Mawanella-Aranayake-Dolosbage zone. A smaller band appears along the Kegalle-Ruwanwella road. They include coarse and fine-banded grey varieties and less frequent pink, poorly banded rocks, and resemble in all details the rocks of the Dambulla area to the north.

This western group of gneisses appears therefore to bound the khondalite-charnockite series on the north-west as a lenticular band tapering at both ends and interrupted by a belt of basic hornblendic and calciferous gneisses (the Kadugannawa gneisses). The latter appear to me to correspond to Fermor's calc-gneisses, which are regarded as metamorphosed sediments closely related to the khondalite series. It is possible therefore that these biotite-gneisses on the northern and north-western side of the charnockite-khondalite series are also to be regarded as metamorphosed sediments of the same age as the calc-gneisses, and that the higher degree of metamorphism and complete obliteration of their original characters are due to the invading Wanni intrusives.

Isolated occurrences of similar rocks have been observed further to the west. In the absence of other evidence there is no reason to suppose that these have any connexion with the Bintenne group. They may be the effect of metamorphism in any area in which pegmatites have been freely injected into a more basic rock. In some exposures they seem to be the result of alteration of rocks of charnockite type by multiple injections of pegmatite as a network or as parallel veins. In the Kirillapona quarry near Colombo blocks of hypersthene granulite may be seen completely enveloped in pegmatite. The gradual passage of charnockite into a streaky black and white gneiss may be traced on the Mirigama-Kotadeniyawa road. The other well-banded biotite gneisses of the western part of the island have probably a similar origin.

A broad band of fine grained grey gneiss has been extensively quarried at Arangala, 8 miles east of Colombo. It varies from an even grained granular rock, light or dark grey in colour and with no trace of banding, to a well-banded biotite-gneiss. It consists of quartz in long ribbons, with orthoclase, which is mainly perthitic and subordinate plagioclase, also biotite more or less abundant, generally irregularly disposed, but in the banded varieties occurring as lenticular streaks with some garnet. Zircon in unusually large crystals is prominent. Microcline is absent but micropegmatitic growths of quartz and felspar are common.

The biotite-gneisses of the eastern Bintenne area, dip everywhere conformably under the khondalitic rocks at the junction and appear to represent the floor on which the great mass of the sediments now represented by the khondalite-quartzite-marble series were laid down. The thickness of the remaining rocks of this series with its intercalated charnockitic intrusions has been estimated at over 30,000 feet, and must have been originally very much greater. The rise of the geo-isotherms in the underlying gneisses resulting from the deposition of this enormous thickness of sediments must have been sufficient to produce a new phase of metamorphism in the gneiss and this probably accounts for the difficulty in determining the actual junction of the schists and the gneissic floor.

Adams (p. 511) remarks on the resemblances of the gneisses of the Sigiriya area (on the northern side of the schist zone) to the rocks of the Canadian shield, which suggest in their appearance an advanced stage of the digestion of masses of basic igneous rock by an invading magma now represented by an acid gneiss. The gneisses of the eastern Bintenne show very similar features, and in places the earlier stages of the process which eventually produced large areas of nearly uniform character may be seen. They differ from the Bengal gneiss of India as described by Wadia (*Geology of India*, p. 54-55) in containing as far as is known, no intercalated beds of limestone or dolomite; and in carrying few accessory minerals. A more detailed study of the area will be required before their actual relationships are known.

Khondalite Series

(See Plates XI and XVIII)

An extensive series of schistose and gneissose rocks comprising quartzite or granular quartz rock as its principal member, fissile quartz-schists, finely banded quartz-felspar gneisses with or without biotite and garnet, impure crystalline limestones, and a peculiar variety of

garnet-sillimanite schist, occupies the greater part of the central hill-zone and extends in a narrow band to the coast at Trincomalie. From their field relations it is obvious that they belong to a distinct group which can be separated from the other gneisses of the Island.

The name Khondalite was proposed by Walker (*M. G. S. I.* Vol. XXXIII, Pl. III) for a garnet-sillimanite-graphite schist included in a series of similar rocks in the Kalahandi state of north-eastern Peninsular India, and the accompanying series of schistose rocks was called by him the khondalite series. It is described as an assemblage of well-defined schists comprising, in addition to the garnet-sillimanite schists, garnetiferous quartzite and pyroxene-scapolite rocks which are probably metamorphosed calcareous sediments.

The general similarity of type and mode of occurrence of the Ceylon rocks suggests that they belong to the same schistose series and may be called by the same name. The rock types described are however, as pointed out by Walker, by no means peculiar to these two areas.

The principal member of the series in Ceylon is quartzite or granular quartz rock which forms extensive bands sometimes several hundred feet thick and traceable for many miles along the strike. The rock is generally traversed by three or more sets of joint planes, which split it up into small fragments at the outcrop, but is interbanded with coarsely granular, hard, unjointed quartz-rock. These hard bands stand out prominently above the surface of the jointed rock on the beach at Trincomalie, where they are well exposed. A similar band of greyish glassy quartz-rock interbanded with the granular jointed rock at Pankulam on the Anuradhapura-Trincomalie road was found to contain very numerous small prisms of tourmaline, and may therefore be a vein rock. According to Adams (p. 459) the hard quartzites sometimes show many minute fluid inclusions.

The quartzites occasionally contain small patches of orthoclase and rare garnet. In some localities highly fissile quartz-schists composed of quartz in thin leaves separated by finely granular felspar are found. The felspar of these rocks is almost always highly kaolinised near the outcrop, and the rock breaks down under very slight pressure into quartz-sand. Good specimens were however obtained from the tunnel for the Hydro-electric works near Norwood, the alignment of which runs through a steep ridge of rocks belonging to the series. One specimen shows long drawn out ribbons of quartz with a few needles of sillimanite in a narrow band, and a wider parallel band in which the quartz includes irregular patches of felspar and also numerous thin

elongated inclusions and a few idiomorphic rhombs, also of felspar. The felspar of the various inclusions is mainly microcline, the rest being perthitic orthoclase. A second specimen showed alternate bands of quartz in long ribbons with sillimanite, and finely granular felspathic bands with a little sillimanite, the felspars being mainly microperthite with subordinate microcline. The rock contains a few garnets, which are in many cases undergoing alteration. The garnet shows a ragged edge against crystals of biotite and is surrounded by felspar showing incomplete microcline twinning and myrmekitic quartz, which is included in both felspar and biotite. A third specimen was coarser and more granular in texture, consisting of quartz, microcline and microperthitic orthoclase, with biotite in irregularly oriented flakes, and strings of sillimanite needles mostly included in the quartz.

Varieties corresponding exactly to Walker's khondalite are rare. The only specimen free from felspar was picked ·up in a district outside the khondalite area. It may however be mentioned that these artificially transported blocks are very common around the salt-pans of Hambantota. They are brought down from the Badulla District as ballast for the empty carts by carters who come down for salt. Around the Palatupana salt lagoon these transported blocks, which are mainly specimens of the khondalite series, are so numerous as to give the impression that the series outcrops there.

The particular specimen, which was said to have come from the Badulla District, was composed almost entirely of garnet, sillimanite, and graphite, with very little felspar. The graphite was especially abundant. In general, however, the sillimanite-garnet rocks of Ceylon are unduly rich in felspar and poor in graphite, which in fact is quite rare. Nearly typical rocks are found in the Hangili-ela near the road bridge on the Welimada-Badulla road, and again in a quarry about 1 mile from Bandarawela on the Welimada road. The Hangili-ela rock shows long drawn out lenticles of crushed garnet between bands of quartz and abundant sillimanite. Under the microscope the garnet bands are seen to consist of rounded individuals containing very numerous quartz prisms which are grouped in the central part of the crystal, leaving a clear zone round the margin, and also brown rutile and zircon in small proportion. The sillimanite is in bands of inter-matted prisms most of which lie parallel to the length of the band, though many are at right angles to this direction. The quartz is in narrower parallel bands, with a few needles of sillimanite, and mostly has the form of long thin ribbons, showing undulose extinction. Orthoclase is present amongst the quartz, but is very rare. No

graphite is seen in the slides, but dark reddish brown rutile is common in the sillimanite or the garnet, and the sillimanite band encloses a string of ilmenite crystals. The Bandarawela specimen shows a little more felspar and also a few patches of calcite and some sheaves of epidote crystals where the calcite is in contact with garnet.

Another variety poor in felspar and approximating to the Indian types is well exposed along the Passara-Namunukula road. In the hand specimen it shows large rounded garnets of uniform size about 20 mm. in diameter, regularly distributed through a greenish grey fibrous ground mass of sillimanite and quartz. The microscope shows a little microperthitic felspar in fine grains in the quartz-sillimanite bands. The garnets in some instances show very ragged outlines and are bordered by a sillimanite-garnet mosaic on one side and on the other by quartz-sillimanite. This rock appears to have a wide distribution, but it weathers so rapidly that fresh specimens are hard to procure. The fresh rock is very hard and tough, but the felspar undergoes rapid kaolinisation and the garnets are converted into limonite pseudomorphs. Adams (p. 487) found the garnet to be almandine with up to 33 per cent. of ferrous oxide and ascribes the rapid weathering of the mineral to the presence of this protoxide base.

Corundum-Sillimanite Rock

An unusual variety, which undoubtedly belongs to the khondalite series, has been described by Coomaraswamy (*Administration Report 1904, Mineralogical Survey*, p. 1-3). It consists of sillimanite and corundum with subordinate orthoclase-microperthite. The corundum forms violet-coloured tabular hexagonal crystals up to 20 mm. in diameter. The sillimanite occurs in parallel and radiating groups, and isolated individuals, the latter generally idiomorphic, and is much coarser than usual in the khondalites : the prisms may be as much as 50 mm. in length and 2.5 mm. in diameter. The rock was not found *in situ:* it occurs as boulders on the face of the Haputale escarpment on Kalupahana and Haldummulla estates and is evidently derived from some outcrop near the crest of the ridge. Similar tabular crystals of corundum have been found in the surface soil on Cleveland and Ormidale estates, 20 miles to the west of Haldummulla and not far from the line of strike in that area, and in gem gravels above those estates, associated with knots of sillimanite crystals. The band of corundum-sillimanite rock has therefore apparently a considerable lateral extent.

In the more felspathic varieties bands of fine-grained quartz-felspar mosaic alternate with quartzose bands containing a small proportion of sillimanite. The garnets generally lie in the felspathic bands. They are commonly wider than the main part of the felspathic band, which widens out rapidly near the garnet. The sillimanite-quartz bands similarly bifurcate to enclose the garnet, giving a marked stream-line effect which is very conspicuous in slightly weathered specimens.

Some specimens from near the eastern boundary of the series show abundant biotite. In a specimen from Uramya the garnets occur in bands of granules with strings of biotite flakes, between finely granular bands of very fresh orthoclase and plagioclase mosaic, with plentiful sillimanite. The garnet granules are flattened and tail off into strings of biotite and sillimanite at the ends. They contain abundant inclusions of the usual quartz prisms and also felspar, biotite, and sillimanite. The sillimanite needles form a well defined border to the flattened faces of the larger garnets and merge into the tail of small garnet granules, mica, and sillimanite at their ends. The minerals are all fresh and have sharp edges: the rock appears to have undergone crushing and recrystallization.

Interbanded with these sillimanite-bearing rocks are many quartzo-felspathic rocks with a little biotite and garnet. The felspar is nearly all microperthitic. The garnets if present do not show the characteristic inclusions. Quartz is largely in long thin ribbons but partly intergrown with the felspars. The rocks are indistinguishable from some of the acid leptynites and granulites found outside the khondalite area but from their field relations they appear to belong certainly to the series.

Associated with the quartzose rocks described are many well-defined bands of crystalline limestones all more or less dolomitic. For convenience these will be referred to as marbles. A detailed petrographical description of some members of this group was given by Coomaraswamy (*Q. J. G. S.* Vol. LVIII, Pt. 3, p. 399-422). They are generally fine to very coarse-grained, composed mainly of calcite with intergrowths of dolomite and rich in accessory minerals. They show a well-marked banding with alternations of coarseness of grain and proportion of accessory minerals. Some bands consist of pure calcite: others are a mixture of calcite with dolomite in granular individuals, or intergrown poikilitically. These are usually colourless, but pale flesh-coloured and greenish varieties have also been noted. The darker bands contain abundant silicates of which a greyish olivine (forsterite) dark ·green pyroxene (diopside or hedenbergite) and pale

phlogopite are the most common. Other non-silicate minerals of frequent accurrence are pyrite, graphite, magnetite, pale blue apatite, and spinel. Brown tourmaline is found in limestone near Mahawala-tenne and was recorded by Coomaraswamy in association with the rare mineral serendibite at Gangapitiya near Kandy. A description of this mineral by the discoverer is given in the paper quoted.

The olivine occurs as large rounded prisms which are colourless or greyish. The mineral has high refraction and double refraction and should probably be classed with forsterite. The grey colour was shown by Coomaraswamy to be due to the deposition of iron-ore along cracks in the crystals. The crystals are nearly always cracked and penetrated by calcite or greyish serpentinuous material. In certain specimens the forsterite is surrounded by a narrow reaction rim of minute prisms of colourless pyroxene projecting at right angles to the surface of the forsterite. Examples of these are described by Adams (p. 494). The forsterite crystals are enclosed in dolomite, and the formation of the rims is ascribed by him to reaction between the magnesium-iron-silicate of the forsterite and the calcium-magnesium carbonate, with the production of a zone of calcium-magnesium-iron silicate at the contact.

The pyroxenes are light to dark green in hand specimens but nearly colourless in thin section. The paler varieties are to be classed as diopside and the darker probably as hedenbergite. They very frequently occur as good prisms with rounded edges, but granular coccolite groups are also common Pyroxene is less common than forsterite in the body of the band, but near the edges and especially where the marble is in contact with rocks of the charnockite series, it becomes very abundant and the calcareous rock passes over into contact rocks consisting mainly of pyroxene with scapolite and phlogopite.

The mica occurs as small crystals of a pale yellow colour. They are nearly colourless in thin section, but show the nearly uniaxial figure characteristic of phlogopite. The crystals are often found in groups which stand out as knobs on a weathered surface. They sometimes attain considerable size and commercial mica has been obtained from bands of a very coarse phlogopite rock with large idiomorphic diopsides and some orthoclase, which occur in, or on the margin of, the marble.

Clinohumite was identified by Coomaraswamy and G. F. H. Smith in marbles at Getembe near Kandy. It is also abundant in a band of marble that can be traced along the face of the Haputale escarpment. The mineral forms rounded grains scattered through the rock, or strings

and clusters. Some of them show one or two crystal faces. At Kandy the mineral was obtained in good crystals, measurements of which provided the identification. In a specimen from the Elahera road the clinohumite, besides occurring as granules with partially developed crystal faces, forms large irregularly shaped bodies filling the interspaces between the carbonates.

Graphite in hexagonal flakes and pyrite are common as accessory minerals. In a marble from Delwita estate, east of Kurunegala, chalcopyrite was found in small proportion. Pale blue apatite, which is sometimes mistaken for corundum, though obviously much softer, is also common as rounded prismatic crystals.

Pale amphiboles are of rather rare occurrence in the marble itself. Tremolite in fine needles, mixed with abundant brucite in hexagonal scales, was found filling a cavity in limestone on North Matale estate. Pink, blue, green, and colourless spinels are also found in the rock, though much more common in the contact zones.

The marbles rarely form conspicuous features, the exception being the long escarpment to the east of the Matale-Dambulla road 2 miles south of Nalanda resthouse. In general the soluble rock is rapidly weathered and is found in the valley bottoms. The surface has always a characteristic black colour. The calcite and dolomite dissolve at different rates, and a skeleton of dolomite laths is sometimes left between the pits formed by solution of the intervening calcite. Weathered blocks of this nature have frequently been mistaken for elephant's teeth.

Though crystalline magnesian limestones are known to exist outside the area occupied by rocks of the khondalite series, they are only extensively developed in that area. The field relations of the rocks show that they are interbanded with members of the khondalite series. Good exposures which reveal the relations of the rocks are seen on the Badulla-Taldena road, at Weragantota near Alutnuwara and along the Matale-Nalanda road. At Hangili-ela a highly impure flesh-coloured or pale-green limestone with very abundant pyroxene is seen interbanded with quartzite and khondalite. The limestone band at this point has been squeezed out into a string of lenticular bodies, and tongues of impure calcite penetrate cracks in the quartzite.

Distribution of the Khondalite Rocks

The boundary of the khondalite series of rocks in Ceylon corresponds roughly with that of the central mountain system of the Island. A well-defined belt of the same rocks continues as far as Trincomalie and

outliers are found capping the hills above Rakwana to the south and crossing the Vavuniya-Horawapotana road in the north of the Island. On the south and east the boundary seems to coincide with the foot of the escarpment above the low gneissic peneplain. Rocks of the series are exposed down to the edge of the escarpment below Mahawalatenne and at Wellawaya, where the boundary between khondalite and gneiss is well defined. From this point it runs north, crossing the Batticaloa road at Bibile and continuing to Uraniya. Here the Mahaweli ganga appears to have cut its way down to the underlying gneiss and the edge of the khondalite series is set back to the west. Good exposures are seen on the left bank of the river near Alutnuwara, and further north along the Elahera road. A persistent quartz ridge running nearly north and south past Giritale tank on the Polonnaruwa road seems to be the eastern boundary for about 50 miles. The strike then bends steadily to the north-east, the khondalite band running out to sea between Nilaveli and Trincomalie while the charnockites, which are intimately associated with the khondalite, extend for another 20 miles to the south-east. ·

On its eastern flank the boundary is not so well-defined. It appears to run from Nilaveli at first south-west and then more southerly close to Habarana where marble is the prominent rock, and then to follow the western wall of the Nalanda-Matale valley, as far as Matale. From here onwards the boundary is uncertain. Khondalite and marble are seen near Kandy and Peradeniya and isolated outcrops are found near Gampola and Nawalapitiya. On the Colombo-Ginigathena road a strong band of quartzite and quartz-schist, continuous with the ridge above Norton bridge through which the Hydro-electric tunnel is bored, crosses the road at mile 60. Quartzite and sillimanite-garnet rock are found at intervals for a few miles to the east of this, and the boundary of the series lies between Kitulgala and Yatiyantota. Between this road and Ratnapura the boundary has not been traced. It lies somewhere in the dense jungle-covered south-westerly-facing escarpments of the Adam's Peak range. Outlying occurrences of limestone are known to exist in Teppanawa village and on Dela estate where a bed of limonite also exists. The ' heavy beds of quartzite ' reported by Adams as seen on the road about 4 miles north of Ratnapura are vein-quartz. Further east khondalite was reported by Parsons in the Kiribatgala range, but I consider this doubtful. Sillimanite-garnet rocks and limestone-contact rocks are however found in the Maha dola between Ratnapura and Balangoda, and the steep Petiyagala range above Balangoda is capped by remnants of a thick quartzite bed.

An outlying block of quartzite with a bed of marble crosses the road between Horawapotana and Kebittigollewa. The quartzite ranges have a north-east strike. They seem to extend for some distance to the north-east, but die out a short distance on the other side of the road. Marble of the usual type is found at Kunchuttu, and at Kirigollewa on the road from Horawapotana to Medawachchiya. The two exposures evidently belong to the same band. The quartzites however are not seen on this road. Several narrow bands of quartzite cross the road between Anuradhapura and Mihintale and marble appears in a quarry in the Weli-oya 3 miles north of Mihintale. These rocks lie on the curving line of strike of the Kebittigollewa beds and may possibly be a southerly extension of the group. No sillimanite-garnet rocks have been observed amongst them.

Another well-defined outlying patch of the khondalite series is found capping a ridge at Pelpatha, 5 miles east of Kegalle. The rocks seen on the ridge about a mile north of the road are, in ascending order, diopside-scapolite contact rocks, sillimanite-garnet-felspar rocks, brownish marble with the usual silicate minerals, and quartzite. The width of the exposure here is probably half a mile. On the main road only quartzite appears, crossing the road at mile 53.

A few isolated bands of quartzite and some obscure outcrops of marble are seen in the western part of the Island, at Hulombuwa, 6 miles west of Kegalle, south of Kurunegala, near Wellawa station, north and west of Galgamuwa station on the northern line, and at Eppawala and several other places on the Kekirawa-Talawa road. These may possibly be remnants of a series of bands of the khondalite series caught up in the invading charnockite and Tonigala granite but their field relations are obscure, the outcrops are widely scattered and the evidence in favour of the above view is insufficient.

A band of marble can be traced from near Madampe resthouse in south-eastern Sabaragamuwa along the road to Hambantota, as far as Timbolketiya. Other limestone outcrops have been noted between Embilipitiya and Panamura. In the hill country above this, marble is seen on Rangweltenne estate above Rakwana, and also along the bridle path from Bulutota to Deniyaya. Sillimanite-garnet rocks and quartzite are found in association with the marble on the lower ground : they have not been observed in the hills above, but some sugary white leptynites with scattered garnets from near mile 82 on the Madampe-Liyangahatota road seem to belong to the khondalite group. There is evidently an extensive area of the series in this region, but its boundaries are not known.

Marble interbanded with charnockite and garnetiferous quartz-felspar rocks is also found in the Kataragama hills east of Tissamaharama in the Hambantota District. It is not certain that these belong to the khondalite series, though their mode of occurrence is similar.

It will be noted that the khondalite series has a very much wider distribution than is suggested by Adams' map, which shows only small patches near Pattipola, Namunukula, and Passara. The distribution of the quartzites shown by Adams does not accord with my observations.

Distribution of Principal Types

The quartzites, as already stated, are the predominant members of the series. They reach their greatest development near Trincomalie, where they form prominent ranges of hills and are exposed in bold headlands projecting into the bay on both sides, and into the sea at several points. Between Nilaveli and Trincomalie the road appears to cross quartzite, at right angles to the strike, for a distance of over 4 miles. Another band with a width of over a half a mile crosses the road just outside Trincomalie town. The beds are here vertical, but in Fort Frederick the dip is flatter and an anticlinal arch is seen under the Residency on Dutch point. To the south-east the dips are again vertical and quartzite continues to be the predominant rock as far as Kinniyai on the west side of the bay

The band of quartzite can be traced to the south-west but the charnockite sills which are everywhere interbanded with the khondalite series become steadily more important. A very strong band of quartzite continues, however, past Giritale tank and for many miles to the south, where it apparently forms the eastern boundary of the series.

The quartzites are also strongly developed in the Passara district, particularly along the Madulsima range: the Lunugala peak above Passara town is a nearly vertical quartzite. They are also prominent in the central part of the hill-zone, around Galaha and in the Maskeliya district, and outcrop at intervals along the face of the scarp above the Ratnapura-Haputale road, and in the terrace between that road and the Mahawalatenne escarpment.

The typical sillimanite-garnet rocks with large garnets are best seen along the Passara-Namunukula road. They can be traced at intervals however along the Haputale-Ratnapura road, a good outcrop of highly decomposed rock being seen at mile 92. They are also common on the edges of the Horton Plains plateau and along the face of the great

southerly-facing escarpment down to the beginning of the low-country peneplain. Isolated occurrences have been noted on the eastern flank of the Adam's Peak range, in the Maskeliya-Norton district, and at Peradeniya and Gampola, near Kandy. They appear again near Kitulgala and in the outlier at Pelpatha.

In the northern extension of the series sillimanite-garnet rocks outcrop near Matale in an anticlinal arch on the Rattota road and can be traced at intervals along the Matale-Trincomalie road, as far as Trincomalie. On the eastern side of the band they are less conspicuous, but specimens have been found on the Habarane-Polonnaruwa road and in the escarpment above Alutnuwara.

The distribution of the marbles, as far as I have been able to map them, does not agree with that shown on Adams' map. The most important band is that mapped by Coomaraswamy in the neighbourhood of Kandy. It outcrops on both sides of a synclinal trough, the axis of which runs NNW-SSE and dips to the NNW. The eastern limb dies out near Kandy, but may be represented further to the north-west by the exposures to the east and north-west of Kurunegala (Delwita and Wellawa). The western cannot actually be traced but it appears to be continuous with the wide band which appears at Wattegama and continues to Matale. East of Matale many parallel bands appear, as the result of folding. The band is continuous from Matale to Nalanda. For the next few miles it has not been traced, but east of Sigiriya the outcrop is over a mile wide. This is the trough of a flat synclinal fold. On the Habarane-Polonnaruwa road the width is still nearly a mile. The band then crosses the railway and the Trincomalie road and would therefore appear to bend towards the north-west. Isolated outcrops appear however along the road, especially at Gal Oya, where the band is over 200 feet wide, and smaller exposures are seen a mile east of Kantalai and on Orr's hill, at Trincomalie. Parsons reported impure limestones in what is now the Trincomalie dockyard and their presence seems to be indicated by springs which deposit lime.

The Badulla marble, which shows several outcrops in the neighbourhood of the town and especially along the Taldena road, is possibly a continuation of the marble seen along the Ratnapura-Haldummulla road and again at the Diyaluwa falls and to the west of Passara. It can be traced as far as Taldena and appears again near Alutnuwara, but has not been traced further. Some narrow bands of limestone appear on the same line of strike at Minneriya, and may represent the continuation of the band.

A parallel band appears at intervals near the top of the Diyawinna escarpment and at Mahawalatenne, and again at Wellawaya and Randeniya. The isolated exposures south of Bibile and along the Bibile-Uraniya road probably represent the continuation of this band. There is no evidence of folding between Diyaluwa and Wellawaya: the two bands must therefore be independent.

On the western side of the khondalite area marbles are not conspicuous. Some isolated obscure outcrops have been noted near Hunuwella, east of Ratnapura, near Dela station, at Ratnapura itself, and to the north-west of the town in Teppanawa village. These lie on a prolongation of the line of the lower or Mahawalatenne band. The upper band is again seen in the cliffs above Ratgama estate and at Eratna. It is not seen on the other paths leading to Adam's Peak from the west but might easily be missed in the thick jungle.

The most westerly exposure of marble which undoubtedly belongs to the khondalite series is the Kunchuttu-Kirigollewa band in the outlying area of khondalites on the Vavuniya-Horawapotana road. The exposure at Mihintale, 15 miles to the south may be a part of the same band. The isolated exposures along the Kekirawa-Talawa road and further to the west, near Galgamuwa, are referred to later. They are entirely surrounded by gneisses of the Wanni type, and may not be related to the khondalite series.

South of the main area of the khondalites marbles are found along the Madampe-Hambantota road between Madampe and Timbolketiya, and again near Liyangahatota. A parallel band is exposed between Embilipitiya and Panamure. Adams figures four parallel bands. The area is one of folding and the bands are probably repetitions of the same folded bed.

The isolated outcrops in the north-west of the Island are described on page 158.

Origin of the Series

On lithological evidence the assemblage of quartzites and marbles would naturally be considered to be a highly metamorphosed sedimentary series. The origin of the sillimanite-garnet rocks has been discussed on chemical grounds. Analyses show that the Indian khondalites contain a very high proportion of silica and alumina and an insignificant proportion of alkalies. As pointed out by Walker (*M. G. S. I.* Vol. XXIII, p. 10) they do not correspond in composition with any known igneous rock. Adams (p. 456) has discussed the

subject more fully, with reference to analyses of Ceylon khondalites made under his direction, and quoting F. W. Clarke (*Data of Geochemistry* 1916, p. 28) points out the resemblance in composition between a composite analysis of fifty-one Palaeozoic shales to that of the Ceylon garnet-sillimanite rocks. Bastin (*J. Geol.* 17, p. 442-472), also quoted by Adams, gives three criteria for discriminating between schist or gneiss formed by the metamorphism of a shale from one formed from an igneous rock. They are :—

1. Presence of alumina in a ratio considerably in excess of equality as compared with the combined lime and alkalies present.

2. Dominance of magnesia over lime.

3. Dominance of potash over soda.

In the four analyses made by Adams all these conditions are fulfilled, the excess of alumina over combined lime and alkali being especially striking. It may be noted that in the corundum-sillimanite rock described on p. 123 as a member of the series, where corundum (alumina) replaces in equal proportion garnet (magnesia-iron silicate) the alumina must be even more preponderant.

The conclusion arrived at is that the sillimanite-garnet rocks represent metamorphosed shales, and that the whole series is a highly metamorphosed group of sediments representing sandstones, shales, and limestones. The quartz-felspar rocks with a little garnet and no sillimanite, which are interbanded with the other rocks, may, in some cases at least, be regarded therefore as metamorphosed arkoses or felspathic sandstones. Adams suggests that the high alumina content of some of the sillimanite-garnet rocks may indicate their production from a rock akin to the laterites of the present day. On the same grounds the corundum-sillimanite rock might be considered as a recrystallized bauxite. The formation of the original rocks from which the crystalline metamorphics are derived would require exposure of the surface of the earlier formed sediments to atmospheric action under climatic conditions similar to those that produce laterite. It is to be noted however that the sillimanite-garnet rocks alternate with quartzites, sometimes in narrow bands and that laterite is not normally formed on the surface of such acid rocks as sandstone or grit.

The presence of monazite, rutile, and zircon, which are found in most of the members of the series by crushing and concentrating the rock, can easily be understood if the rock were formed by the denudation of a land surface of older igneous rocks.

Thickness of the Series

The thickness of the khondalite series with its intercalated charnockites as determined on sections where the dip is regular, is of the order 30,000 to 40,000 feet. This takes no account of the quantity of rock that must have been removed in the course of ages from the upper part of the series. Between Trincomalie and Nilaveli the dips are practically vertical. The width across the outcrop of the nearly vertical beds is again about 30,000 feet, making allowance for the folded area at the southern end.

Kadugannawa Gneisses

A thick lens of hornblende gneisses of a type not common in the rest of the island borders the khondalite-charnockite area of the hill country on its western side between Matale and Peradeniya. The rocks are best seen on the Kadugannawa pass, where they are apparently folded in a steep anticline. The eastern limit of the fold forms the prominent Alagalla-Kadugannawa range. The band can be traced for about 10 miles to the south. Similar rocks are found near Nawalapitiya and in the Dolosbage district, but they do not extend to the Colombo-Ginigathena road. East of the Matale-Kandy road they form several conspicuous hill ranges and extend down to the Rambodagala road, but they seem to pinch out rapidly in a northerly direction. Another group of hornblende gneisses, associated with quartzite and ill-defined bands of marble, is found south of Kurunegala. It is probably a part of the Kadugannawa group.

The rocks of the Kadugannawa group form a lens about 8 miles across at its thickest part, and tapering out at both ends. The length of the lens is about 30 miles. The lenticular form is in part, at least, due to folding. They are typically dense, black, glittering hornblende rocks, with more or less biotite and felspars. They may be massive or schistose, sometimes strongly so. Banding of the light and dark minerals is not prominent. Some banded varieties show alternate hornblendic and felspathic bands. In others, narrow bands consisting mainly of pyroxene appear. Calcite is always present, as crystals with sharp rectilinear boundaries against the other minerals, as interstitial matter, and as irregular patches in hornblende or felspar. In one variety the pyroxene and amphibole are distributed regularly in equal proportion in a felspathic ground mass.

The hornblende is bright or dull green to pale greenish brown in colour. It is usually hypidiomorphic and includes felspar and biotite.

The pyroxene is colourless in thin section, probably diopside.   In some of the schistose varieties the pyroxene is strongly altered and the hornblende includes numerous mica flakes arranged parallel to the cleavages. This is evidently due to local crushing; in general the minerals are remarkably fresh and sharp in outline.   Apatite is often very plentiful as an accessory mineral and zircon is nearly always present while sphene is rare.

Interbanded with the hornblende gneisses are diopside-scapolite-sphene rocks of the usual type.   These may form quite narrow well-defined bands or wider zones in which there is a gradual transition from one type to another.   They are common on the Kadugannawa pass and widely developed again on the road from Mawanella to Rambukkana. In this direction the Kadugannawa gneisses extend up to the small outlier of khondalites and marble at Pelpatha (see p. 128), the most westerly exposure of the khondalites.   There is a wide band of diopside-scapolite rocks at the contact of the calc-gneisses and the khondalites.

The gneisses are penetrated by pink granitic rocks of Tonigala type and also by numerous white pegmatite veins.

The Kadugannawa gneisses bear a close resemblance to the calc-gneisses of Fermor (*M. G. S. I.* Vol. XXXVII, p. 243) described as occurring in association with khondalites usually at their junction with the gneissic granites, in the coastal plains of Vizagapatam.   These rocks are however stated to contain wollastonite and microcline, which I have not seen in the Ceylon rocks : the number of slides examined is however small.   .

The calc-gneisses of Vizagapatam are regarded by Walker (*R. G. S. I.* Vol. XXXVI, 1907) (quoted by Fermor) as metamorphic calciferous sediments.   Their age relative to the khondalites is left doubtful but they are considered to be younger than the gneissose granites and charnockites of the region.   The Kadugannawa area in Ceylon, where the gneisses are extensive, is a region of folding and possibly faulting. The recognizable khondalites show gradually increasing dips as their western boundary is approached and are succeeded to the west by vertical bands of biotite-gneisses of undetermined affinities, pink Tonigala gneisses and then a wide zone of Kadugannawa gneisses.   These have a steep easterly dip in the Alagalla-Kadugannawa escarpment and a westerly dip a few miles further to the west.   Easterly dips appear again a few miles to the east of Pelpatha : at Pelpatha the last rocks of the khondalite series dip steeply to the west.   No khondalites have been seen between Pelpatha and Kadugannawa, but closer search might reveal outcrops of these rocks.   On the other hand it is possible

that the khondalite-quartzite-marble facies pinches out to the west of Kandy and is replaced by the calc-gneiss facies, until Pelpatha is reached, after which charnockite predominates and neither khondalites nor calc-gneisses are seen. A diagrammatic section is shown below.
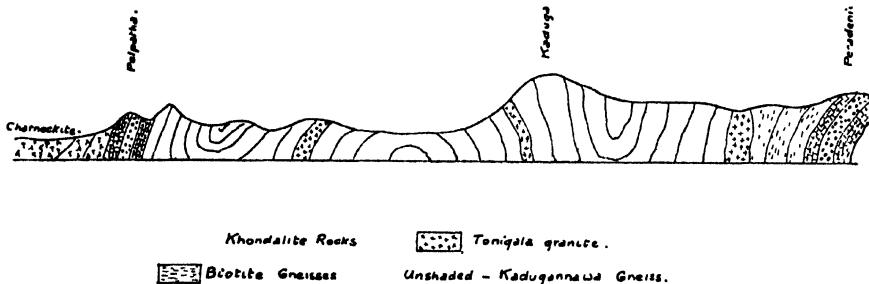
Fig. 4. Diagrammatic section along Kadugannawa Pass.

West of Matale the khondalite-marbles again dip under the calc-gneisses which rise like a wall along the western edge of the Matale-Nalanda valley. The calc-gneisses are steeply tilted in this area also, and further to the west, on the Kurunegala-Rambodagola road, a sharp fold is seen. Marbles appear to the east of this road in a position corresponding to that shown in the diagram above. It is therefore probable that the relation of the calc-gneisses to the khondalites in this area is correctly represented and that they overlie the khondalite-quartzite-marble facies. There is however no reason to regard them as a distinct formation. Marbles are prominent all along the junction between the two facies of rocks and the Kadugannawa gneisses may be regarded as metamorphosed calcareous sediments of the same original formation.

The Charnockite Series

The name charnockite was given by Holland (*M. G. S. I.* Vol. XXVIII, Pt. 2, 1900) to the hypersthene-granite of Pallavaram near Madras, and the group name Charnockite Series to the consanguineous rocks associated with it in South India. The type rock is described as an even-grained crystalline aggregate of quartz and potash felspar as the two most abundant of the constituents, with smaller quantities of oligoclase, rhombic pyroxene approaching hypersthene in optical characters, opaque iron-ores and an occasional granule of zircon; this represents the acid member of the series. At the other end are basic

rocks mineralogically equivalent to the norites and composed of pyroxene (hypersthene and augite) plagioclase and iron-ores, often with hornblende, and frequently garnetiferous. Intermediate varieties between these two are the most abundant. They have an apparently composite structure, all the minerals of the series being frequently found in one hand specimen with a tendency to gather into groups. Ultra-basic forms, or pyroxenites, composed of hypersthene, augite, hornblende, sometimes with olivine, green spinel and magnetite are also known.

The whole series is regarded by Holland as of igneous origin and intrusive into the older gneisses and schists, representing a series of extrusions of slightly differing composition from one parent magma.

Rocks answering precisely to the description of the charnockite series of Walker are widely distributed in Ceylon, which petrographically as well as geographically, is a part of the Indian continent. They reach their greatest development in the south-west quarter of the island, where, as far as my observations go, they are continuous over an area of 4,000 square miles, and also form numerous thick sills between the schists of the khondalite series. Isolated exposures are common amongst the apparently younger Wanni gneisses of the north of the island and intrusions probably belonging to the series are found amongst the Bintenne gneisses of the east.

The name charnockite is strictly applicable only to the hypersthene-granite described by Holland. The other members of the series are undoubtedly consanguineous and it is convenient to use the term to cover the whole group and distinguish them from other pyroxene-granulites. The word charnockite must therefore be taken to connote in this monograph any member of the charnockite series as distinguished from unrelated pyroxene-granulites.

Petrology of the Ceylon Charnockites

In hand specimens the more acid members of the series are granular rocks with a clear grey colour on a perfectly fresh fracture, which changes very quickly, even in specimens kept under cover, to a characteristic greenish or bluish-grey tint. The component minerals are arranged in alternating light and dark bands or lenticles. Quartz, either colourless or more generally dark bluish-grey in colour, and greenish-yellow and white felspars can be seen to make up the lighter bands, and dark green or black pyroxene or hornblende to predominate in the darker bands. Brown mica is often conspicuous, and small garnets are very frequently present. The basic members are dark green and nearly black in colour with less pronounced banding. Hypersthene

can sometimes be distinguished by its lighter colour from the darker augite and hornblende. Garnets are very numerous in some varieties and may reach 20 mm. in diameter though generally smaller.

The charnockites vary in grain from a glassy-looking very compact fine-grained rock with a strongly marked conchoidal fracture, to coarse pegmatitic types with yellowish brown schillerized felspar, bluish quartz and brown mica. The great majority of exposures are however of medium grain, and the individual crystals are roughly equal in dimensions.

The mineral banding may be discernible only under the microscope, but it is generally visible in hand specimens, except in the very fine-grained varieties, and is often developed on a large scale, the light and dark bands being several centimetres in width. Dark segregations of lenticular form, or parallel-sided bands, containing a great preponderance of ferro-magnesian minerals, are also of common occurrence in the lighter coloured, more acid, rocks.

Many specimens, especially those from the eastern side of the charnockite area have a schistose appearance. This is due to the rapid alternation of strings of small pyroxene and hornblende crystals with equally narrow felspathic bands and ribbons of quartz. Elongation of quartz crystals into lenticular or ribbon-like bodies is a common feature. In these schistose specimens it is developed on a finer scale than usual. The micaceous varieties are not always conspicuously banded: the biotite may be scattered quite irregularly through the rock and is only rarely concentrated in definite bands.

Rocks corresponding to the typical acid charnockite and the basic norite are, according to Holland, comparatively rare in India. By far the greater proportion belong to intermediate types, either as the result of interbanding of acid and basic varieties or of the occurrence in more or less regular distribution of the various minerals, quartz, orthoclase, and plagioclase felspars, pyroxene, hornblende and biotite, in the same rock. Holland comes to the conclusion that the intermedite varieties are the result of the direct consolidation of the igneous magma from which the rocks of the series are derived, and that the extreme varieties are the result of more perfect differentiation induced by local conditions. Precisely the same description applies to the Ceylon members of the series, and the same conclusion may be drawn as to their origin. The various modifications are described in the following pages and the differences that have been noted are pointed out.

Drawings of some specimens of the principal types are shown in Plates XII to XV.

Acid Varieties

Varieties corresponding closely to true charnockite may be found in all parts of the Island. They form wide bands in the great mass of intermediate charnockites in the south-west of the island, and wide or narrow sills intercalated in the khondalite series. They are of a lighter grey colour than the more basic rocks, but not so light as might be expected from their acid composition. The dark colour of the rock surface is due to the dark bluish grey tint of the abundant quartz. This however does not show the characteristic acicular inclusions of the Indian charnockite described by Holland, which I have observed only in one specimen out of some hundreds.

They consist, like the Indian charnockite, of a granular intergrowth of quartz, orthoclase, subordinate oligoclase and a small proportion of hypersthene. The orthoclase frequently has microperthitic inclusions of albite, and also shows spindle-shaped bodies of quartz. Some patches of myrmekitic quartz in orthoclase occur as interstitial matter, but the proportion is much less than in the more basic varieties. The hypersthene is in very irregularly shaped crystals. They may be scattered through the ground mass or disposed in chains parallel to one direction. The quartz and more rarely the felspars show the same tendency to elongation. Iron-ores, magnetite, and ilmenite are present in small quantities and apatite and small zircons occur as accessory minerals.

A significant difference from the Indian charnockite is the complete absence of microcline from uncrushed varieties of the rock. The potash felspar in the Ceylon rocks, whether acid or intermediate, is invariably orthoclase. I have only found microcline in two specimens of pyroxene-granulite in Ceylon and these were undoubtedly crushed rocks. The specimens examined by Adams also show no microcline. The extreme rarity of acicular inclusions in the quartz has already been noted. Apart from these two characters, the description of the Indian charnockite exactly fits the Ceylon rocks.

A typical specimen from Matugama, about 30 miles from the west coast of the island shows abundant hypersthene with characteristic pleochroism, and opaque iron-ore, in a granular aggregate of quartz, orthoclase and subordinate plagioclase. The hypersthene is mainly concentrated in chains of very ragged crystals. The other minerals are in interlocking grains of about equal size, with a fair proportion of smaller quartz grains. Apatite and small zircons occur as accessory minerals. The quartz contains strings of irregularly shaped cavities and opaque scales, but does not show any acicular inclusions (Plate XII, Fig. 1).

A specimen from Udugama in the southern part of the area also agrees with the description of charnockite. It shows crystals of hypersthene generally irregular in form but occasionally hypidiomorphic, scattered through a moderately coarse ground mass of quartz and orthoclase with rare oligoclase. A specimen from a wide sill amongst the khondalites near Welimada in the east-central part of the area shows a stronger tendency to elongation and parallel orientation, a characteristic of the Ceylon rocks. The ground mass is the usual quartz-orthoclase-microperthite with subordinate plagioclase. On the extreme east of the charnockite-khondalite area, where the rocks have a well-marked schistose appearance, the chains of hypersthene crystals lie in a ground mass of finely granular quartz-orthoclase which is separated into bands by parallel long thin lenticles of quartz (Plate XII, Fig. 2).

Noritic Varieties

True norites are also rare, most of the basic varieties rich in pyroxene, hornblende, or mica showing a fair amount of untwinned felspar and even quartz, in addition to plagioclase. They are as widely distributed as the true charnockites, but are distinctly more numerous on the eastern side of the charnockite-khondalite area. They nearly all show well-marked mineral banding. A specimen from near Welimada contains about 50 per cent. augite and hornblende, with subordinate and smaller hypersthenes. In the felspathic bands a few small hypersthenes are present and the augites are large. In the more basic bands augite and hornblende are intergrown in small crystals with a definite elongation parallel to the banding. The augites show lamellar twinning and in both augite and plagioclase the twin lamellae are curved. A more basic variety from Madulsima has about 70 per cent. of hypersthene, augite and brown-green hornblende, with labradorite felspar. A variety from east of Lunugala village is more normal. It consists of very evenly distributed equi-dimensional granules of bluish-green augite and hypersthene in andesine felspar, which makes up 50 per cent. of the rock and also shows bent twinning lamellae (Plate XII, Figs. 3 and 4).

An augite-biotite norite from Elkaduwa shows about equal proportions of pale-green augite and hypersthene in fairly well-defined bands between bands of labradorite felspar which contains abundant spindle-shaped inclusions of twinned and untwinned felspar. The biotite is irregularly oriented, and much iron-ore is intergrown with the pyroxene.

Ultra-basic Varieties

The ultra-basic varieties belong to two distinct types. At the contact of limestone of the khondalite series with intrusions of charnockite, wide bands of a pyroxene rock composed almost wholly of diopside are found. These are evidently the result of reactions between the lime rock and the intrusive and are described with the other mixture rocks of the zone of contact. Intrusive ultrabasic rocks with hypersthene are found under the same conditions as the other members of the series, mainly as sills amongst the khondalites. They are conspicuous amongst the quartzites on the shores of Trincomalie bay, as bands a few feet wide. On a weathered surface they have a fibrous appearance due to the parallel arrangement of dark prisms of pyroxene, and at first glance suggest hornblende schists. In the hand specimen the dark green, nearly black, augite and light brown hypersthene are clearly distinguishable. The microscope shows them to consist of equal proportions of pale augite, hypersthene and a monoclinic pyroxene with faint pleochroism like that of hypersthene, together with iron-ore and a little green-brown hornblende and very rare interstitial felspar. The minerals are quite fresh except along certain lines, along which the pyroxenes are almost entirely converted centrally into bastite (Plate XIII, Figs. 1 and 2).

A different ultra-basic variety, which appears to be a large lenticular intrusion in the khondalites, is seen near Balangoda. The rock is quite massive and consists mainly of brown-green hornblende and iron-ore with biotite, and very rare hypersthene in thin idiomorphic prisms. The interspaces are filled with andesine felspar, which includes crystals and small crescent-shaped bodies of hornblende. Other varieties are made up mainly of augite and brown-mica and iron-ore, with abundant apatite.

In addition to these non-garnetiferous rocks many varieties are found in which garnet is a prominent constituent. These may have all degrees of acidity, varying from acid rocks in which pyroxene, garnet, and dark minerals are rare to ultra-basic types in which garnet, pyroxene, and hornblende make up over 90 per cent. of the rock. They are described in a separate section.

Intermediate Varieties (Non-garnetiferous)

The intermediate varieties have a wide range of composition and are difficult to classify because of the large number of mineral species which they contain. They may however be divided into (*a*) varieties without garnet and with subordinate biotite; (*b*) varieties without garnet and with abundant biotite; (*c*) garnetiferous varieties.

(a) Varieties without garnet and with little or no biotite

In these the pyroxene is generally hypersthene accompanied by less augite, but sometimes replaced entirely by the monoclinic pyroxene. The crystals are generally very irregular in outline but slender prisms of hypersthene and rarely of augite, sometimes showing terminations, are occasionally found embedded in quartz, accompanying the allotrio-morphic minerals. Augite is quite frequently pleochroic—green to greenish-yellow—and it often shows lamellar twinning and fine stria-tions. Dillage is found in some unusual varieties. Hypersthene and augite may be intergrown and the rhombic pyroxene may completely enclose augite. They may however occur in distinct bands. Horn-blende often accompanies the pyroxene: the rock is then traversed by parallel bands of hornblende with a little pyroxene and of pyroxene with a little hornblende. In other varieties however, particularly the rather basic types from near Trincomalie, the three minerals hypersthene, augite and hornblende are quite evenly distributed as a coarse mosaic. The hornblende belongs to two types, one the common basaltic type, with pleochroism X-pale yellowish-brown, Y-brown, Z-deep brown, and the other green with pleochroism X-pale greenish-yellow, Y-yellowish-green, Z-olive green. The former is more common in the varieties rich in pyroxene, and the latter in rocks with a pale pyroxene, but is not entirely confined to these. A colouring intermediate between the two is often seen.

Of the felspars plagioclase, varying from oligoclase to andesine, is generally in excess of orthoclase. The potash felspar is largely micro-perthitic. The inclusions of albite are sometimes so coarse as to be visible under the lens. The plagioclase often contains minute prisms of quartz. In many specimens the twinning of the soda-lime felspars is very irregular and imperfect and inclusions of patches of one felspar in another are common. This is generally the result of crushing.

The accessory minerals are apatite and zircon, the former being more prominent in the basic hornblendic varieties where the prisms often lie in chains and may form an appreciable proportion of the rock. Zircon is not limited to the acid rocks, but is sometimes in high proportion in the basic members.

A peculiar feature of the intermediate varieties of the series in Ceylon is the frequent occurrence of calcite, which is not mentioned by Holland as one of the constituent minerals of the Indian varieties. The calcite frequently occurs as large grains comparable in size to the quartz and felspar grains, and with some approach to crystalline form. More often however it forms strings and flakes amongst the granular quartz-felspar.

In regions where the charnockites are associated with the limestones of the khondalite series opportunities for the absorption of lime by the invading charnockite intrusions were frequent. A great development of lime-rich mixture rocks has resulted on the margins of the limestone bands; apart from these the charnockites of the khondalite-charnockite area are not notably rich in calcite. More numerous examples of this type are seen in the low-country, away from the khondalite zone. It is of course possible that the great intrusions of charnockite in the south-west of the island have completely absorbed the younger khondalites. But while admitting that some of the calcite in the charnockite may be foreign origin it appears to me that much of it is to be regarded as an original mineral of the magma.

(b) *Micaceous varieties without garnet*

The micaceous varieties contain a marked proportion of brown mica, partly in small flakes scattered through the body of the rock with irregular orientation, and partly in sheets along certain planes, which naturally become fracture planes, and are then seen to be covered with a continuous sheet of mica flakes. Where the micaceous planes are closely spaced the rock becomes fissile and slaty.

In other respects the micaceous varieties resemble the non-micaceous. The banding of the ferro-magnesian minerals is rather more definite and much of the mica lies in the more acid felspathic material which separates the pyroxenic bands. The mica is pale brown to dull purplish-grey in colour and nearly uniaxial. In a few specimens, generally those which contain diopside, or colourless pyroxene, the mica is chestnut-brown in colour and appears to be phlogopite. The mica may be associated only with hypersthene or with pyroxenes and hornblende in varying proportion. The accompanying felspars are orthoclase and plagioclase and quartz may be in any proportion within the usual limits.

In the leptynites described later, in which mica is a prominent constituent and pyroxene is rare or absent, the mica is probably of secondary origin. Some of the mica in the micaceous charnockites also appears to be result of the breaking down of pyroxenes under strain. The irregularly oriented flakes scattered through the felspathic, non-pyroxenic, portions of the rock and the biotite of the well-defined bands without pyroxene which lie parallel to bands of pyroxene with little or no mica in many rocks, are probably original minerals.

The micaceous varieties have a wide distribution and may occur, like the leptynites, in zones isolated amongst thick masses of non-micaceous or feebly micaceous character. They are especially prominent on the north-western border of the hill country in the Kegalle-Kandy-Kurunegala area which is a region of folding. They evidently

correspond to the biotite-charnockites described by Iyer in the North Arcot district in India (*R. G. S. I.* Vol. LXVI, p. 113), a region which shows other resemblances in its geology to that of Ceylon (Plate XIII, Figs. 3 and 4).

(c) *Garnetiferous varieties:*

Garnet is a very common mineral in charnockites of all degrees of basicity, but more particularly in the basic and ultra-basic varieties. The crystals are usually small except in certain ultra-basic types in which garnets up to 30 mm. in diameter are sparsely distributed in a ground mass which contains abundant garnets of smaller size. In extreme cases the garnet may compose 50 per cent. of the rock.

Besides the rocks in which garnet appears to be an original mineral and not the result of dynamo-metamorphism there are amongst the charnockites many bands of an obviously crushed rock containing abundant garnet and biotite of secondary origin. These have some resemblance to the garnetiferous leptynite described by Holland (*M. G. S. I.* Vol. XXVIII, Pt. 2, p. 142) as occurring at the junction of charnockite and norite. They are described later in this monograph under the heading leptynites (p. 152). The varieties now discussed are those in which the garnet appears to be an original mineral, though it is not always possible to be certain on this point.

In the rare acid garnetiferous varieties the garnets may be quite irregularly distributed or arranged in chains parallel to, but at some distance from, chains of hypersthenes. Both minerals are embedded in a ground-mass of quartz and orthoclase-microperthite in which the quartz bodies are sometimes lenticular but sinuous and not in parallel orientation.

A typical example is found in the Galle district as a wide band of light greenish-grey charnockite in close proximity to a band of cream-coloured granulite with rare garnet and no pyroxene, which seems to correspond to Holland's garnetiferous leptynite. The hypersthenes are perfectly fresh: the garnets lie in a parallel chain with no hypersthene; they have a rounded form and there is nothing to suggest that they are not original minerals formed at the same time as the hypersthene.

A more basic variety is shown in Plate XIX, Fig. 1. The garnet and hypersthene show remarkably clean cut outlines. The ground mass is mainly plagioclase felspar with some perthitic orthoclase.

In the ultra-basic varieties evidences of reaction between garnet and the other minerals are very common and examples of unmistakably

fresh garnet and pyroxene or hornblende in contact or even in the same slide are rare. An exception is shown in Plate XIX, Fig. 2, which represents a specimen of doubtful origin, probably from some locality between Dondra head and Matara. The rock is a dense even-grained aggregate of garnet, green augite, and hypersthene. The minerals are intimately intergrown with perfectly sharp contacts and are all quite fresh.

A poikilitic intergrowth of garnet and hypersthene in a rock from the Dambatenne group of basic garnetiferous charnockites, described later, is shown in Plate XIV, Fig. 4. The rock in question is composed of garnet, hypersthene and brown hornblende, all with perfectly sharp outlines and showing no sign of alteration.

These specimens showing simultaneous and independent crystallization of garnet and pyroxene are however comparatively rare. More commonly the garnet and pyroxene are in extremely ragged crystals, either mingled in the same band or in distinct parallel bands, in a matrix which shows a distinctly leptynose structure. Sometimes these bands are broken by an exceptionally large garnet from which strings of ragged garnets and pyroxenes stream off in a tail. Large hypersthenes with the same tail of small individuals are also common. The appearance strongly suggests the kataclastic structure of a sheared rock in which large crystals have been shattered and the fragments dragged away. The accompanying felspars however show the usual granular-crystalline form and if the rock has been shattered they must have been recrystallized. It is possible however that the structure is due to shearing movements in the rock during consolidation. The segregation of the constituents of the ferro-magnesian minerals apparently began while the rock was still in a viscous condition and the ferro-magnesian segregations were drawn out and broken up, eventually solidifying in the form they now present.

Plate XIX, Figs. 3 and 4, represent typical structures in these sheared garnetiferous charnockites.

Basic Garnetiferous Varieties

The acid and intermediate garnetiferous charnockites are widely distributed amongst the non-garnetiferous rocks and no relationships have been established between the various exposures examined. A well-defined group of highly basic garnetiferous norites is however found on the eastern side of the khondalite-charnockite area. Their greatest development is seen on the Dambatenne group of tea-estates, east of Haputale. Here they overlie the great sheet of normal non-garnetiferous charnockite of the Haputale escarpment.

The Dambatenne rocks are dark coloured, generally medium-grained, and showing dark red garnets evenly distributed in a ground mass of dark green augite and hornblende and reddish brown hypersthene. The garnets may be concentrated in certain bands or in groups, and occasionally large individuals up to 30 mm. in diameter are seen. In one specimen dull-brown porphyritic crystals of hypersthene occur. Many of them show evidence of crushing, and some are strongly sheared and converted into a basic banded leptynite.

Under the microscope the typical uncrushed rock is seen to be composed of garnet, brown hornblende, augite with feeble pleochroism from bluish-green to yellowish-green, strongly pleochroic hypersthene and a monoclinic pyroxene with pleochroism almost as strong, which gives extinction at angles of up to 37° with the cleavage-intersection. In thick slides the hypersthene shows nearly the same colour as the augite in one position, and may be even a stronger red than the garnet in the other.

The minerals are in allotriomorphic grains of approximately the same proportions, the garnet and hornblende sometimes showing some crystal form. In most specimens they are grown together in individuals of about equal size, with only a small proportion of smaller crystals. Either one or other of the minerals may preponderate: in extreme varieties either pyroxene or hornblende may be entirely wanting; or the hornblende may be concentrated in narrow bands between bands containing both amphibole and pyroxene.

The felspar is in very small proportion; in parts of the rock only one or two interstitial grains may be seen. It is usually labradorite or andesine.

The garnet nearly always encloses small crystals of pyroxene and hornblende and also large patches of plagioclase and minute prisms of quartz, which may be so numerous as to give it a spongy appearance. Iron-ore is often abundant and rutile and zircon are occasionally seen, also, in a rare instance, calcite. The inclusions are generally concentrated in the middle of the garnet, leaving the peripheral zone clear. An unusual variety of rock composed of garnet and felspar was found as a boulder at the foot of the Kataragama hills in the south-east of the Island. Basic garnetiferous charnockites of the Dambatenne type occur in this range, and the rock described may be an extreme variety. It consists of an intergrowth of garnet and orthoclase in long interdigitated streaks, with rare green pyroxenes (see Plate XXII, Fig. 1).

The rocks show numerous examples of the structures described by Holland in the related garnetiferous charnockites from the Salem

district (*M. G. S. I.*, Vol. XXX, p. 124). The garnets are very often isolated from the other minerals by a thin corona of granular plagioclase. Strings of similar material separate the closely adjacent garnets of a group or penetrate the individuals. The pyroxene and hornblende are sometimes disposed in elongated individuals or grains with iron-ores forming an outer border to the felspar corona. In some specimens all the garnets are surrounded by a fringe of small hooked or curved tongues of pale coloured pyroxene which form a micrographic intergrowth with the felspar. The surrounding pyroxenes are then seen to present a very ragged outline on the side facing the garnet: the vermiform pyroxene bodies do not however extend right across the felspar corona to the outer rim of pyroxenes. Similar growths of hornblende are occasionally seen. The micrographic intergrowth occasionally fills cavities in the garnet.

Micrographic intergrowths of pyroxene and plagioclase are however quite common in the same specimens at a distance from the garnets. They may lie in a cavity in the middle of a crystal, or group of crystals, of hypersthene or in the felspathic bands between the dark minerals. Many of them have a roughly radial structure with a minute round garnet or pyroxene at the centre; in others no central body exists.

In some specimens the intergrowth of pyroxene or hornblende and felspar near a garnet is on a coarser scale. An incomplete ring of garnet surrounds a central area filled with granular hypersthene and plagioclase. The outer edges of the garnet are sharp and regular while the inner boundary is ragged. Examples of the reaction rims are shown in Plate XV, Figs. 1 to 4.

Holland ascribes the formation of these micrographic growths to a breaking up of part of the hypersthene with liberation of silica and formation of garnet. Pyroxene is stable at high temperatures and readily changes to amphibole under dynamic action at low temperatures. He suggests the possibility that at some intermediate temperature garnet may be formed instead of amphibole.

The micrographic intergrowths of pyroxene and felspar are found in the Ceylon rocks at some distance from the garnets as well as on their borders, and they are also found on a larger scale in some non-garnetiferous rocks. It appears to me therefore that these structures do not necessarily indicate the formation of garnets from pyroxene by secondary metamorphic action, but that they may be due to changes in the composition of the solidifying magma during unduly rapid consolidation.

The ultra-basic garnetiferous varieties reach their greatest development, as already stated, on the Dambatenne group of estates, above the great Haputale sill of more nearly normal non-garnetiferous charnockite. A narrower band of a similar rock is seen near Koslande, at the base of the Haputale sill. The Dambatenne sill can be traced to the westward as far as West Haputale estate. Basic garnetiferous rocks are found again in the stream at Ramboda bridge. East of Dambatenne they appear again in considerable thickness in the Namunukula range. The region is one of folding and the connexion of these exposures has not been proved. Probably however they represent extensions of the Dambatenne sill, which thins out in all directions.

Some rocks of the same type are found above the Mahawalatenne escarpment, and an apparently continuous band occurs near the foot of the eastern escarpment from Bibile as far as the Elahera road. North of this non-garnetiferous ultra-basic rocks continue as far as Trincomalie where they are numerous but never of great width. All these exposures seem to belong to a distinct zone, parallel to the Dambatenne band at a lower horizon.

Some isolated occurrences have been noted near Pupuressa and again near Nawalapitiya and on the eastern slopes of the Adams Peak range, on the road to Dalhousie estate. All of these quite probably belong to the Dambatenne sill. In the south-western sector where charnockite predominates, they have not been noted, except high up on the southern escarpment of the Deniyaya-Rakwana hillmass. This again is possibly a continuation of the Dambatenne sill.

A highly garnetiferous basic variety of charnockite is also found interbanded with less basic pyroxene-hornblende rocks, garnetiferous pyroxene-leptynites, marbles and the usual contact rocks, in the Kataragam range, 20 miles to the north-east of Hambantota. The range is surrounded on all sides by biotite-gneisses, and the relation of this group to the charnockite-khondalite series has not been determined. The garnetiferous basic rock consists of garnet, brown hornblende and pale greenish augite with about 25 per cent. of plagioclase. The minerals are all quite fresh and the garnet is free from inclusions of quartz, but encloses small grains of pyroxene and hornblende.

Distribution of the Charnockites

The rocks of the charnockite series occupy the whole of the south-west quarter of the Island. If, as I hope to show, the garnetiferous

leptynites with which they are associated are to be regarded as
sheared portions of the charnockite mass, the rocks may be said to
be continuous from the west coast between Colombo and Tangalle
to the foot of the western escarpment of the hill-country. At the
northern end they are cut off by the younger Wanni gneisses, which
intrude long nearly parallel bands into the charnockite. The char-
nockite bands between these intrusions taper out gradually to the
north, and charnockite ceases to be the predominant rock roughly
on the line Colombo-Kurunegala, though exposures are known to the
north-west of this. At the other end the boundary of the great
charnockite mass is doubtful. East of a line between Deniyaya and
Tangalle the rock is rarely seen.

In the hill-zone the charnockites are extensively developed as sills
intercalated in the older rocks of the khondalite series. The sills
vary in thickness from a few inches to great sheets which in the
highest part of the hill-country are over 3,000 feet in thickness. The
intrusive nature can be seen in certain sections where the charnockite
envelopes portions of the younger schists. In one locality transverse
offshoots of a sill included in quartzite can be seen traversing the
enclosing wall-rock.

On the eastern side of the hill-zone the charnockite and khondalite
rocks appear to be cut off by the biotite gneisses at the foot of the
main escarpment, but the country to the east has not been fully
explored. They continue, still intercalated in the khondalites, as far
as Trincomalie, apparently reaching a great thickness immediately
to the south of Trincomalie bay and again near Kantalai. On the
coast at Trincomalie and for 10 miles to the north quartzites of the
khondalite series predominate. The northern boundary of the khon-
dalite series is not clearly defined. Charnockites are found in isolated
exposures in the north and north-east of the Island surrounded either
by rocks apparently belonging to the khondalite series or by the
younger Wanni gneisses. A pyroxene-granulite is found in the most
northerly exposures of the crystalline rocks at Mankulam, and on the
Mankulam-Mullaittivu road, and again at Cheddikulam near Mannar
on the west coast.

A few instrusions of pyroxene-granulite of an unusual type are
found amongst the Bintenne biotite-gneisses, particularly near
Komari, the most eastern point of the Island. Though they differ
in character from the other members of the series, a transition may
be traced, and their relationship to the charnockites seems to be
established.

The rocks may therefore be said to extend over the length and breadth of the Island. In the south-west quarter they are predominant if not exclusive; in the hill-zone and along a belt extending to Trincomalie, they are of equal importance with the khondalites; in the low country on either side of this they are decidedly subordinate.

Distribution of the Different Types

No regular distribution of the various types of the series has been made out except in the case of the basic-garnetiferous variety described above. In a traverse across the strike in the south-west quarter of the Island slightly differing varieties of the intermediate group alternate, with occasional acid charnockites, many garnetiferous leptynites and rarer ultra-basic rocks. The latter seem to occur only as narrow bands.

Both acid and basic varieties are found as thin sills in the khondalites and again as massive intrusions several hundred feet thick. Micaceous varieties are more numerous along the west coast and along the western flank of the hill-zone, a region of shearing. The compact, fine grained, slightly sheared rocks with peculiar silky appearance are confined to the eastern border of the hills. The localized distribution of the basic garnetiferous types, already described, makes it probable that the other varieties are also developed in accordance with some system of differentiation from a parent magma, but more extended observations are required.

The isolated exposures in the northern part of the Island show some differences from the normal. The Cheddikulam exposure, near Mannar, is an acid charnockite with calcite, occasionally with good crystal outlines. It is remarkable as the only specimen examined microscopically which shows regularly oriented needles in quartz.

The Mankulam rock, from the most northerly outcrop in the island also shows calcite, and a little pale pyroxene, partly converted into brown mica and green hornblende. Basic and garnetiferous varieties also occur in this region.

The dull greenish-grey pyroxenic intrusives from Komari and the neighbourhood are intrusive in the biotite gneisses. They contain a small proportion of dull green diallagic augite in a ground mass of quartz and orthoclase. Some dark green-yellow hornblende is present and may replace the pyroxene entirely. Plagioclase is rare. The orthoclase is finely perthitic and contains numerous small prisms of quartz. A crystal of microcline was noted in one specimen. Calcite is generally present, sometimes in conspicuous amount and well-

crystallized and some specimens show large yellow sphenes. Hypersthene has not been identified in mocroscope slides or in crushings of the rocks, but one slide shows a pale non-pleochroric rhombic pyroxene, associated with dull green diallage in coarse microperthitic orthoclase which is traversed by narrow zones of crushed felspars. Zircon is very abundant. The rocks therefore appear to be related to the charnockites.

Some interesting varieties occur as narrow dykes traversing the older rocks. The offshoot of a sill traversing quartzite in the Hangili-ela near Welimada, already referred to, closely resembles the Dambatenne garnetiferous type. It consists mainly of garnet in large individuals intergrown with pale green pyroxene. The garnets are surrounded by rims of an intergrowth of plagioclase and pyroxene outside which is a ring of pyroxene grains. The pyroxene in the intervening plagioclase may be in the form of rounded granules or of the curved tongues already described, and part of the rim may consist of plagioclase only. Iron-ore is plentiful, sometimes forming curious growths with pyroxene, and some sphene is present. About half a mile away a similar offshoot of a sill penetrates the bordering quartzite. Both sill and transverse vein are composed of hypersthene-augite and brown hornblende with subordinate garnet. Micrographic intergrowths of hornblende and felspar are fairly numerous in the sill, either as fringes to the garnet or independently. In the narrow vein they are much more conspicuous.

A narrow dyke of an entirely different type, also penetrating quartzite, has been noted near Passara. The dyke rock is a finely granular quartz-felspar rock with fairly well-defined leptynite structure. It contains about 25 per cent. of pale pyroxene in strings' of ragged grains in part of its width : in the rest pyroxene is rare.

Dyke rocks somewhat similar to the Hangili-ela rock traverse biotite-gneiss in a quarry 2 miles to the north of Hambantota. They are rather basic in character, consisting of dark green augite in groups or isolated ragged crystals, intergrown with iron-ore and brownish pink garnet. The ground mass is granular quartz, orthoclase and microcline, the latter fairly abundant. Sphene is plentiful and there is some interstitial calcite. In another specimen the augite is partly altered to greenish hornblende.

The nearest known occurrence of charnockite in the vicinity is 12 miles distant. A remarkable narrow dyke of augite-scapolite rock was at one time exposed in the same quarry. This is described on p. 169.

Comparison of the Charnockite Series in Ceylon and India

The sketch map (Fig. 5) shows the distribution of the charnockite series in Ceylon and in India. The Indian Geological Survey Map of 1931, from which the sketch is partially taken, shows however only the areas that have actually been mapped in that country. Charnockites are known to exist in many places outside this area, but they have not been studied in sufficient detail to allow of their discrimination from the other ' unclassified Crystallines, Gneisses, &c.', which still occupy so large an area of the map of Southern India.

The charnockites of Ceylon, like those of India, occur as great intrusions occupying exclusively several hundred square miles of territory and also as minor sills interbanded with the rocks of the khondalite series. They differ from the Indian charnockites in (1) the almost complete absence of microcline (2) the widespread distribution of calcite (3) the prevalence of micaceous types (4) the intercalation
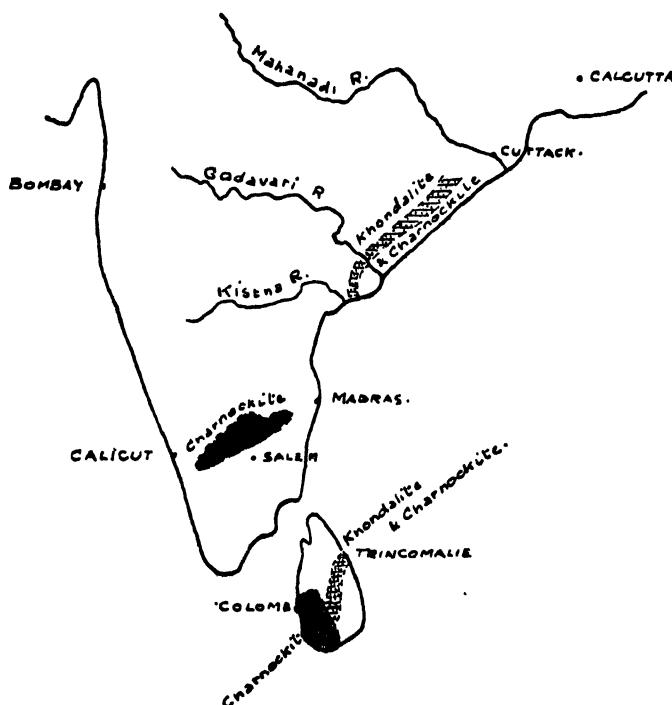
Fig. 5. Distributions of Charnockite and Khondalite in India (from Geological Survey Map of India 1931) and in Ceylon.

of numerous bands of garnetiferous leptynites. In the two latter peculiarities, however, they resemble the rocks of the North Arcot district in which reference has already been made (*R. G. S. I.*, Vol. LXVI, p. 113). It is suggested that the abnormal nature of the peculiar charnockites of that area and the presence of apparent intrusions of garnetiferous leptynite may be the result of regional metamorphism. Though the intrusive nature of the leptynites in Ceylon has not been definitely established there is no doubt that the whole complex in the Ceylon area has been folded and crushed, and that the micaceous character of the charnockites and the schistose character of the leptynites are due to this cause.

Leptynites

The charnockites and norites as a rule show a rough segregation of the ferro-magnesian minerals into parallel bands separated by more acid material, but the banding is not always conspicuous.

Associated with the charnockites and often demonstrably either of the same origin or derived from them by secondary processes are many well-banded gneisses or leptynites, usually showing more or less garnet. The characteristic of these rocks is the finely banded structure. The light and dark minerals are arranged in parallel persistent bands of even width, and light or dark colour, the lighter coloured, more acid, material generally but not always predominating. They are divisible into two classes according to the mode of origin, but the distinction is not always clear. One type has evidently been produced under the same conditions as the charnockites but with an exaggeration of the flow movements which gave rise to their characteristic structure. Some varieties of this type show metamorphism of an original charnockite. The other type is the result of multiple injections of a partly solidified charnockite by later pegmatites. All graduations from a coarse gneiss in which the bands may be several inches wide to a fine-grained almost schistose rock may be found (see Plate VI, Figs. 1 to 4 and Plate XX).

A characteristic feature of the former type, observable in hand specimens as well as under the microscope, is the existence of quartz in long thin leaves or ribbons. Orthoclase occurs in similar attenuated forms but is less common. The term leptynite, which has been variously used, appears to be particularly applicable to these rocks which show the conspicuous thinning out of the constituent minerals, more especially quartz, and is accordingly used to describe them. Holland appears to have applied this term to the nearly white garnetiferous-granulites which are associated with the charnockites of S. India.

The rocks of simliar type found in Ceylon show little or no thinning of the minerals, which are equi-granular, and are more appropriately described as 'acid-granulites. They are evidently however closely connected with the charnockites and leptynites.

In hand specimens the leptynites show parallel bands of acid material, quartz and felspar, with scarcely any dark minerals, alternating with darker bands in which biotite is generally plentiful together with hornblende or pyroxene. Acid and intermediate varieties in which the lighter bands predominate, are more numerous. Basic varieties in which the proportion of light coloured mineral bands is quite small are however found.

Nearly all varieties contain garnet, sometimes in abundance. The mineral is as a rule more plentiful in the basic bands. The crystals are usually arranged in chains but they are not always flattened or elongated like the other minerals. Many varieties show large garnets which lie across and completely interrupt the banding. In some rocks showing a well-marked banded structure the garnets are elongated in a direction at right angles to the banding. In others the garnet grains are remarkably even in size and scattered regularly throughout the rock, independently of the banding of the other minerals.

Hornblende is often distinguishable in the darker bands. It rarely forms continuous thin streaks or wider bands parallel to the main banding. Pyroxene may also be identified in crushings from the basic varieties, when not visible in a hand specimen.

Some of the non-garnetiferous varieties show a less regular banding and are indistinguishable from the composite gneisses formed by the absorption of pegmatite. In some of these the acid bands have the pink tint characteristic of the Tonigala gneiss and its pegmatites. They are almost certainly hybrids. Hypersthene may occasionally be detected in crushings of the darker material.

The highly garnetiferous varieties often show a close resemblance to some varieties of khondalite. Unless sillimanite is extensively developed in these it is difficult to decide to which group they belong. A specimen from a large exposure in the Colombo district where no unmistakeable khondalites have been found shows rather abundant sillimanite in flakes streaking round the garnet or enclosed in it. This is quite exceptional.

Under the microscope the leptynites show similar features. The ground mass is a granular aggregate of quartz and felspars mainly of fine grain, with patches and bands of coarser material. The finer

grained felspathic material is traversed by flattened and elongated masses of quartz, which often become long thin ribbons traversing the greater part of the slide. The quartz in these elongated bodies does not show the same optical orientation throughout. The larger felspars in the non-garnetiferous varieties are almost entirely orthoclase-microperthite and many of the finer grains also show a fine microperthitic structure. The larger individuals frequently enclose prisms of quartz and myrmekite is common. In the more basic garnetiferous varieties plagioclase occurs in varying proportion.

The ferro-magnesian minerals are biotite, hornblende, subordinate pyroxene, and usually garnet. Some varieties however carry no garnet. The biotite flakes may be disposed parallel to the direction of banding, but much of it is quite irregularly oriented. The hornblende individuals are mainly elongated parallel to the banding. They sometimes lie along the edge of the quartz ribbons. The mineral is mainly fresh but secondary uralitic hornblende also occurs.

Garnets may be in strings of small granules lying parallel to the banding and often flattened or slightly elongated in the same direction, or in isolated individuals much larger than any of the other crystals in the rock and showing no relation in form or disposition to the banding. These larger crystals may be very irregular in outline, with tongues of quartz or quartz-felspar mosaic penetrating them. They enclose very numerous prisms of quartz and irregular patches of felspar. Biotite, zircon, and calcite have also been noted as inclusions. Many of the rocks show evidence of crushing: the margins of the felspars are granulated and the plagioclase is very irregularly twinned and intergrown with orthoclase without definite boundaries. The quartz shows undulose extinction and in the well-banded rocks both quartz and garnet often show a strong system of cracks at right angles to the direction of banding.

The garnets are frequently surrounded by a ring of finely granular felspar, but do not show kelyphite borders or reaction-rims. It is rare to find the other ferro-magnesian minerals actually in contact with garnet. Graphic intergrowths with felspar are sometimes seen. In the crushed varieties the garnet is sometimes partially broken down into biotite, which forms a tail to the original crystal.

Calcite is a common constituent of the rocks. It is often well crystallized, but generally occurs as interstitial matter among the felspars. In one specimen it occurs as an inclusion in garnet and is prominent in the granular felspathic corona surrounding the garnet. It is

quite common in rocks containing no lime-bearing plagioclase or ferro-magnesian minerals and can hardly be regarded as derived from the breakdown of those minerals. Moreover it is of common occurrence in leptynites from regions where no other lime-bearing rocks are known to exist, and cannot therefore be the result of absorption of lime from such rocks. It therefore appears to be an original magmatic mineral.

Sillimanite is very rare but it is strongly developed in the specimen already mentioned from the Colombo district, a region where no limestones or other members of the khondalite series are known to exist. The rock in question is exposed on the minor road from Kapugoda to Udupila, 18 miles east of Colombo. It consists mainly of coarse quartz, orthoclase, and plagioclase traversed by streaks of garnet, iron-ore and sillimanite. The garnets are very irregular in form. They are surrounded by a zone of myrmekite and often show a ragged edge against the myrmekite border. They enclose abundant flakes of sillimanite, also biotite and quartz and large masses of iron-ore. The latter are surrounded by a belt of kelyphitic felspar which fills the interspace between the two minerals. Other masses of iron-ore occur as elongated bodies intergrown with biotite, sillimanite, and myrmekite or in a graphic growth with felspar, the aggregate running in streams around and between the garnets. Small patches of green spinel are fairly common in the iron-ore (see Plate XVII, Figs. 1 to 3).

The sillimanite is never seen except near the garnet and iron-ore aggregates. It may be the result of crystallization under some unusual conditions which have resulted in the formation of aluminium silicate (sillimanite) and iron-oxide (magnetite) as separate minerals, instead of in combination as iron-aluminium silicate (garnet) or of decomposition of the early formed iron-garnet under shearing stresses into silliminate and iron-ore.

Excess of iron-ore is not a characteristic of the khondalites, in which the sillimanite is the direct product of metamorphism in an aluminium-rich rock. The rock described appears to be a strongly crushed basic variety of charnockite.

The leptynites show considerable variations in basicity. Acid varieties show a few scattered garnets and thin strings of biotite flakes. In the more basic the garnets are numerous and more closely packed and biotite and hornblende are abundant. Pyroxene is present in varying amount except in the extreme types. A gradual transition from charnockite to leptynite may be traced in specimens from different localities or in an assemblage of detrital rock-fragments obviously

derived from the same outcrop. The hypersthenes become more elong-
ated and are gradually replaced by biotite in the case of acid rocks, or
biotite, garnet and hornblende in the more basic, till only a few relict
pyroxenes can be found, or none at all. The transition has only been
actually observed in one outcrop. In a quarry near Matugama one half
of the quarry face is a feebly sheared micaceous charnockite with elong-
ated hypersthenes in the coarser quartz-felspar and thin strings of biotite
in the finer material. The other is a leptynite rather poor in garnet. It
shows abundance of mica in thin streaks and very rare relict pyroxene.
Typical charnockite and leptynite occur at a short distance from the
quarry on either side.

A similar transition from a rather basic charnockite to a highly
garnetiferous banded rock with abundant garnet can be seen in
specimens from the Madulsima range. The non-garnetiferous charno-
ckites themselves in this area have a peculiar silky appearance on a
weathered surface due to the alternation of strings of elongated
hypersthenes and ribbons of dark-coloured quartz. The leptynites
include intermediate varieties in which hypersthene is still present,
though largely converted to hornblende, and typical banded varieties
with abundant scattered garnets and only a trace of relict hypersthene.
This is a region of strong shearing.

The prevalence of micaceous varieties of charnockite in Ceylon,
especially in areas where folding can be demonstrated, and the
existence of leptynites of all degrees of basicity, corresponding to the
variations in composition of the charnockites themselves, and showing a
gradual transition in composition and structure from these, seems to
me clear evidence that the leptynites represent the product of extreme
alteration of the charnockites along zones of shearing.

The white granulites corresponding to Holland's garnetiferous lepty-
nite are finely granular white to cream-coloured rocks with a few
scattered pink garnets. They are composed of equi-granular quartz
and orthoclase-microperthite in about equal proportion with rare
plagioclase. The garnets are round and contain no inclusions in the
granular varieties. Some examples show signs of shearing: the quartz
is in long ribbons, some of the felspars are crushed and may show
obscure microcline twinning. The garnets are elongated and irregular
in outline with many inclusions. These sheared bands may however
alternate with the usual granular material.

These acid granulites have a wide distribution but the individual
outcrops are not as a rule very wide. An exception is a long wide

band lying parallel with a band of acid charnockite on the Wanduramba road in the Galle district. Another very conspicuous band is seen on the road south from Kalawewa to Galewela. This lies outside the main charnockite area. There is no definite evidence as to the origin of the rocks.

Wanni Gneisses

A distinct group of reddish, pink, or buff-coloured gneisses and granulites of intrusive appearance, apparently closely related to one another, is found in the northern half of the island. The group occupies the low-country from the east to the west coast around the northern edge of the mountain zone. Other less extensive masses of similar rock are found on the north-west flank of the hill-country as far south as the lower Kelani river and again on the east coast between Trinco-malie and Batticaloa. The main mass however corresponds roughly with the low-country known as the Wanni and the group may accord-ingly be called the Wanni gneiss group. It is subdivided in accordance with its distribution into (1) the Tonigala (2) the Kalkudah-Nilaveli (3) the Ritigala and (4) the Ambanpitiya gneisses. The members of the respective groups are more closely related to one another than to those of the others, but they show certain common features. They are all characterized by (1) paucity of ferro-magnesian minerals (2) abundance of magnetite (3) comparative abundance of monazite.

The principal member of the Wanni gneiss group is the Tonigala gneiss, which extends over an area of over 1,600 square miles in the quadrangle Chilaw-Kurunegala-Anuradhapura-Puttalam. Near the coast it is a coarse grained granitic rock with no trace of gneissoid structure. Inland it becomes finer grained, a banded structure gradually appears and on the eastern side of the area the rock is re-presented by banded pink gneisses, well seen at Galgamuwa and near Maho.

In the type locality, the Tonigala quarries, 14 miles south-east of Puttalam on the road to Kurunegala, the rock has a tint varying from greyish-pink to grey. The pink varieties show reddish felspars rather prominent in a finer grained equi-granular aggregate of clear quartz and colourless striated felspar, with a few flakes of biotite and abundant magnetite in good crystals. Under the microscope it is seen to consist of allotriomorphic grains of orthoclase and microcline in about equal proportion with quartz and subordinate oligoclase. The orthoclase is rather coarsely perthitic; it sometimes encloses patches of indistinct outline with microcline twinning and is penetrated along its borders

by myrmekitic quartz. The quartz in the body of the rock is mostly in the form of hooked or curved rounded bodies and is often completely enclosed in felspar. Magnetite is scattered freely through the rock.

The grey variety of the rock from the same quarry is rather coarser in grain. The perthitic inclusions in the orthoclase are on a finer scale: there is no microcline and iron-ore and biotite are rare.

In a quarry near Nikaweratiya and in other exposures on the same line of strike the rock contains a considerable amount of calcite, some of it well-crystallized and apparently an original mineral. The felspars in this zone show very irregular twinning and a very coarse perthitic structure. The microcline may be quite fresh but it is often inter-grown in alternate long narrow bands with a much more highly bi-refringent striped lime-soda felspar. The biotite shows more of a tendency to parallel disposition and green hornblende, epidote, and sphene are common, while magnetite is much less abundant.

Immediately to the east of this line, on the road between Galgamuwa and Anuradhapura, there is a chain of outcrops of marble of the usual dolomitic type at the foot of a strongly defined ridge of pink hornblende gneiss, and several obscure outcrops of the same rock appear in low country a few miles further east. The marbles differ in no respect from those of the khondalite series and quite possibly represent remnants of a band of these rocks which has been absorbed by the invading Toni-gala intrusion. No other rocks which can be considered as altered members of the khondalite series, however, are found in this area, nor within a radius of 30 miles. There are certain bands of biotite gneiss enclosed by Tonigala gneisses which might conceivably be altered siliceous members of the khondalite series, but there is no direct evidence to support this view.

It is also significant that some of the pegmatites which traverse the Tonigala gneiss contain abundant calcite apparently as an original mineral. A wide transverse vein of reddish pegmatite from the Toni-gala quarries consists of coarse microcline, orthoclase, and subordinate oligoclase with large crystals of calcite showing rectilinear borders against some of the felspars as well as smaller bodies and interstitial calcite. A large orthoclase crystal in contact with the calcite is full of highly bi-refringent feathery inclusions except near the contact, where it is quite clear. A large felspar individual on the other side is also full of cloudy inclusions: where clear felspar appears it may be twinned or untwinned. Near the calcite the lamellar twinning is well-defined in a narrow band parallel to the edge of the calcite, but the twinning lamellations die out and the band in contact with the calcite is clear

and untwinned. In places the calcite groups may have sharp contacts with felspar on three sides and pass over on the other into a cloudy mass of microcrystalline matrial with low bi-refringence which contains scales of opaque matter. Another crystal of calcite is completely altered to fibrous tremolite and microcrystalline pleochroic epidote.

The quartzose portions of the rock consist of quartz and microcline or quartz and orthoclase, most of it perthitic, and a little oligoclase, with groups of hornblende-biotite-magnetite, enclosing much calcite and some sphene and also quartz and felspars. The hornblende has the pleochroism greenish yellow—olive green—greenish blue, but the crystal axes could not be determined. It is evident that the rock has undergone extensive alteration since its formation, but it seems clear that the calcite is an original mineral. The pegmatite traverses a large body of the intrusive gneiss and no limestones have been observed within 20 miles of it. It therefore is improbable that the lime is of foreign origin and it is more probably to be considered as part of the original magma.

The Tonigala gneiss extends as far south as the Yagodamulla quarries, 15 miles north of Colombo. The Asgiriya range, near Gampaha is formed of a hornblende gneiss which appears to be related to the group. In the prolongation of the range to the south of Veyangoda pink gneiss of the Tonigala type appears again in Radawana village. This appears to be its southern limit.

In a quarry near Kaduwela a narrow dyke of pink granite with megascopic monazite was seen traversing a rock of the charnockite series, and large irregular intrusions of pink granitoid rock, enclosing blocks of hypersthene granulite. The Tonigala gneisses are therefore of later age than the charnockite series. Banded rocks consisting of alternations of pink pegmatitic material and dark bluish-grey rock with hypersthene are common in this region. They represent lit-par-lit injections of Tonigala granite into the older charnockite rock.

Exposures of the Tonigala gneiss are common along the Puttalam-Anuradhapura road, and less common on the Mannar-Vavuniya road. At Madhu, 20 miles inland from Mannar, there are highly decomposed rocks of the same type. Further to the north at Vavuniya there are wide bands of the Tonigala gneiss, in contact with charnoc-kite, in the Vavuniya quarry. The line of junction is ill-defined and the one type seems to pass gradually into the other. The pink gneiss is of the hornblende type with abundant sphene : the charnockite is of the acid variety : it has an unusual light bluish-grey colour in the hand

specimen and at first sight may be mistaken for some of the eastern members of the Wanni series. It shows however a small proportion of hypersthene.

The quarries at Mankulam, the northern limit of the crystalline rocks, also show coarse pegmatite of the Tonigala type and a banded microcline gneiss with alternations of pink felspathic and micaceous bands. They are also associated with a pyroxene granulite, but the contact of the two rocks was not exposed.

The Kalkudah-Nilaveli rocks ·may be considered with certainty to belonging to the Tonigala group. They all contain magnetite and conspicuous monazite. At Nilaveli the rock is coarse-grained and not distinguishable from the Kalladi granitic types of the extreme west. Here also it encloses blocks of partially digested charnockitic rocks. The numerous ranges of hills that run out to sea as headlands north of Nillaveli are of finer grain and resemble the Tonigala rock. At the ferry 2 miles south of Kuchchaveli there is a thick parallel sill of coarse dark red pegmatite composed mainly of finely perthitic orthoclase with some microcline and oligoclase, traversed by irregular bands of quartz. Magnetite is common as small octahedra in the felspar and in large irregular bodies, bordered by biotite. Zircon is unusually abundant. The crystals are large and are generally cloudy with minute brown and black scales, but with a clear border.

A grey granular acid rock, resembling in hand specimens some varieties of the Tonigala gneiss, is interbanded with charnockites and quartzites of the khondalite series at Andankulam near Trincomalie. It shows under the microscope only coarse perthitic orthoclase and quartz, with a fair amount of calcite, but no microcline. Zircon is plentiful but magnetite only scanty. It is very doubtful whether this should be assigned to the Wanni gneisses; it is possibly an acid member of the charnockite series.

South of the charnockite-khondalite belt the pink gneisses appear again at Kadiraveli and Kalkudah, between Trincomalie and Batticaloa. They differ in appearance from the type rock, being paler in colour and with more conspicuous banding, due to the disposition of magnetite in crystals and grains along parallel streaks. The Kalkudah rock shows megascopic monazite. The southern limit of the group therefore seems to lie somewhere near Batticaloa, where reddish gneisses are also seen, but the boundary between them and the Bintenne gneisses has not been traced.

The two other groups appear to be closely related to the Tonigala gneiss. The Ambanpitiya gneisses form long parallel bands between

members of the charnockite series. Though the connexion has not been actually proved they may be considered as offshoots of the parent Tonigala intrusions which have penetrated the charnockites, and their peculiar characters may be ascribed to this interbanding, on a comparatively small scale, with the older rocks. The type rock of the sub-group is the wide band of pink and buff-coloured rocks that crosses the main Colombo-Kandy road on Ambanpitiya hill. On the western side of the band the rock is a coarse granitoid gneiss indistinguishable from the gneisses of Kalladi. On its eastern side the rock is finer grained and buff-coloured, but it is traversed by streaks of coarser pink quartz-felspar. In some of the rocks of the group the texture is very fine-granular but in the majority it is coarser and the rocks have the appearance of sheared aplitic granites or pegmatites. Magnetite is always present either evenly distributed or in well-defined thin streaks. In one specimen the mineral is so abundant that the rock affects the compass-needle and as the result of its meridional strike long specimens even show polarity. Monazite is present in small amount in nearly all examples and is occasionally megascopic.

Microscopically the Ambanpitiya rock is a coarse intergrowth of quartz, orthoclase, orthoclase-microperthite, and microcline in about equal proportion with rare brown mica and abundant zircon. The felspars are rather irregularly intergrown with indefinite boundaries between the twinned and untwinned portions. The microcline as well as the orthoclase is traversed by rather wide streaks of a highly birefringent twinned felspar. The Ambepussa rock contains a large proportion of fine-grained quartz and microperthitic orthoclase filling the interstices between coarser material of the same character, with rare patches of secondary epidote. The other rocks of the group show similar characters. The leptynose character is often well developed, the quartz especially occurring in long thin lenticles. Microcline is rarer than in the Tonigala type: myrmekitic quartz and inclusions of quartz prisms in felspar are frequently seen.

The rocks of the group are developed principally along the northern boundary of the charnockite area. They are well seen in the type locality at Ambanpitiya, at Ambepussa railway station and along the Kegalle-Ruwanwella road. The band at Ruwanwella can be traced as far to the south-east as Parakaduwa but otherwise they have not been seen south of the Colombo-Ginigathena road. In the hill-country there are thick bands between Kadugannawa and Gampola and again four miles south of Peradeniya but the type has not been seen elsewhere amongst the numerous exposures in the main hill-country. There are

many outcrops near Kurunegala, notably in the Yakdessagala range, and a good exposure in quarries on the Dambulla road at mile 7¼. Further to the north similar rocks form the Bomarukanda range and appear again at Kalawewa, connecting up with the Ritigala group.

At Ambepussa a thick band of the Ambanpitiya gneiss is in contact with the eastern edge of a mass of charnockite which appears to be several miles in width. The charnockite is an acid variety with plagioclase as well as orthoclase, and shows signs of deformation in the bending of the twin lamellae of the felspar. The junction runs approximately north and south. The pink gneiss throws off tongues which penetrate the charnockite and produce near the boundary a pink and grey banded rock exactly like the numerous banded pink and grey rocks that occur along the boundary of the two formations. The later age and intrusive nature of the Ambanpitiya gneiss is thus demonstrated.

To the north of the junction the bands of Ambanpitiya gneiss become more extensive as the bands of charnockite contract and as stated above there is little doubt that they are offshoots of the Tonigala gneiss which have penetrated the charnockite and undergone some slight modification as a result.

Ritigala Group

The rocks of this group show no important differences from those of the Ambanpitiya group except in the variety which forms the Ritigala range. This lacks the pink or buff tinge : it is a rather fine-grained grey granulite with some white felspars of much larger dimensions than the ground mass and contains abundant magnetite. Other specimens from the neighbourhood are indistinguishable from the Tonigala type. A rather coarser variety of pink granitoid rock from Kalawewa is unusual in striking across the general banding of the country, whereas all the other wide bands of the Ambanpitiya gneiss strike conformably with the surrounding rocks. A similar aberrant strike in a hornblendic gneiss of the Tonigala group was observed at Konwewa station. It cannot be decided without more careful mapping that these are definite transverse intrusions. The Konwewa rock appears to be the end of a long folded band and the Kalawewa rock may be another example of folding.

Relation to Indian Rocks

In a brief account of the geology of the North Arcot district of the Madras Presidency published in the General Report of the Geological

Society of India for 1931 (*R. G. S. I.*, Vol. LXVI, Pt. 1, p. 113) mention is made of a newer granite or gneiss, intrusive in the charnockites. The rock is described as a pink gneiss of medium to coarse grain, composed of large crystals of felspar, quartz and biotite, with iron-ore and apatite as accessory minerals. The description fits some varieties of the Wanni gneisses of Ceylon, except that no mention is made of monazite which is everywhere a characteristic constituent of the latter. A grey hornblende gneiss is also mentioned, but no description of it is given.

Some of the numerous granites and granitoid gneisses described by Bruce Foote in the Bellary district (*M. G. S. I.*, Vol. XXV) also resemble petrologically, as far as they are described, the Ceylon rocks, but the microscopic characters are not given. These granites and gneisses are considered by the author to be older than the banded gneisses, amongst which, at that time, the charnockites were apparently included.

Pegmatites

Two distinct types of pegmatitic intrusions are common in Ceylon, characterized by reddish and white felspars respectively, as well as by differences in the accessory minerals they contain. Some of the reddish pegmatites are undoubtedly offshoots of the Tonigala gneiss. Examples at Tonigala and Kuchchaveli have already been described (pp. 157-8 and 160). They consist of reddish orthoclase, colourless plagioclase, and quartz with some biotite. Microcline felspar is often present. They are generally poor in accessory minerals except magnetite, which is often in large crystals, and a little monazite. The rocks are common in the northern part of the Central province and within the Tonigala gneiss area. At Trincomalie they occur as sills up to 20 feet wide, with parallel walls, amongst the rocks of the khondalite series. Similar pegmatites are found in the extreme south of the island near Tissamaharama, intruded in the biotite-gneisses. The multiple injections of red pegmatitic material into the charnockites near the boundary of the charnockite area belong to the same group.

The white pegmatites are remarkable for the large number of accessory minerals they have yielded. They are nearly white in colour except for a variable amount of biotite, and vary in grain from granite to very coarse pegmatite with felspar crystals a foot long. The large quartz crystals which are occasionally picked up in the Kandy district are probably derived from such veins.

This group of pegmatites was designated by Coomaraswamy the Balangoda group, from their great development near the small town of that name. The principal outcrop is a band of zircon-bearing granite 2 miles in length and 100 yards wide which is seen parallel to the foliation of the charnockite on Massena estate above Balangoda. Numerous exposures of similar rock are found in the district, notably at the bridge over the Denegama river, on the Ratnapura road a mile below Balangoda. Some very coarse examples are seen at mile 81⅔ on the same road, and on the northern edge of the Horton plains. The existence of pegmatites in many other places in the same area where they are not actually exposed is indicated by the abundance of their characteristic accessory minerals in stream gravels.

The zircon-pegmatites are by no means confined to the Balangoda district, though their great development there justifies the adoption of the name. They are common throughout the south-western and central parts of the island but have not been definitely recorded from the northern and eastern low-country. An exceptionally large outcrop of zircon granite is seen in Loluwa village, between Mirigama and Kotadeniyawa, standing up in wall-like masses. A similar massive outcrop occurs near Bibile, on the eastern margin of the hill-country. This envelopes blocks of charnockite. Some very wide bands are seen north of Matale and again in the Ratnapura district. In both these areas they frequently degenerate into quartz veins. The numerous veins of glassy quartz seen on the Uva patanas between Haputale and Welimada are apophyses of pegmatite veins of this group.

The characteristic accessory mineral of the rock is zircon either yellowish brown or black in colour. The megascopic crystals seen in the rocks named above are the brown variety. Some of the other accessory minerals have been detected in the rocks themselves, notably monazite, thorianite, and beryl; the others were found by washing decomposed material from the outcrop of the dykes.

Monazite occurs as strings of rounded grains in crushed pegmatite at Nugatenna, east of Teldeniya where it was first noted by Coomaraswamy, and on Denegama estate in the Balangoda area. It is common everywhere either in rounded grains or in good crystals. Crystals up to 20 mm. long were found in a decomposed pegmatite at Nuwara Eliya, with xenotime and zircon. The monazite of the beach sands at Kaikawela near Bentota on the west coast, which were exploited economically for a time, is also derived from neighbouring outcrops of pegmatite (see p. 185).

The pegmatites are particularly rich in minerals containing uranium, thorium, and metals of the rare-earth group. The mineral thorianite, essentially an oxide of thorium and uranium, is of frequent occurrence in the Balangoda pegmatites and the micaceous offshoots of the dykes. Allanite is of rather frequent occurrence. Thorite, fergusonite, and xenotime have been washed out of decomposed dykes and tscheffkinite, tantalite, aeschynite, and zirkelite have been found in adjacent river gravels. Of other minerals chrysoberyl, topaz, andalusite, rutile, and cassiterite have been washed out of decomposed material. Ilmenite is common: masses of over 100 lb. in weight have been found in river gravels in the Balangoda district. Tourmaline is abundant either in the felspathic portion or as needles in the quartz, which sometimes becomes a tourmaline-quartz rock.

It is remarkable that monazite and zircon are characteristic minerals of the charnockite rocks, the Wanni gneisses and the younger pegmatites of Ceylon. The occurrence of monazite in charnockite in India has already been noted (*R. G. S. I.*, Vol. LXVI, p. 113). In Ceylon it is found in small quantity in all the more acid rocks of the group and more plentifully in the shear zones in which graphite veins so frequently are situated. In the Wanni gneisses monazite is conspicuous in the finer grained granitoid and gneissoid rocks, but not especially abundant in the pegmatitic facies, except in rare cases, as in the Kaduwela vein already noted (p. 103). The white pegmatites of the Balangoda type, are demonstrably younger than the charnockites, but their relations to the Wanni gneisses are unknown. In them the monazite reaches its greatest concentration and it is accompanied by numerous other minerals containing thorium, uranium, and the rare earth metals. I am uncertain how far this may be considered as evidence of consanguinity with the charnockites and Tonigala granite, in which the existence of monazite as an accessory does seem to indicate a relationship. In the younger pegmatites uranium is present as well as thorium, though the thorium is predominant. I have not detected any uranium minerals in numerous concentrates from crushed Tonigala gneiss and charnockite.

A dyke of unusual character cuts across the banded khondalites and charnockites in the Hangili-ela section. It has a width of 6 feet between well-defined walls. The weathered surface shows numerous large garnets which are very closely packed in some parts of the dyke. Under the microscope it shows large twinned oligoclase crystals and rarer large orthoclase in a finer aggregate composed mainly of plagioclase with some large very irregular quartz bodies in places and

plentiful brown and green mica. The smaller garnets are euhedral: the larger have an irregular form but sharp edges. They enclose the usual quartz prisms, also patches of felspar and brown mica and shoals of small needles with low bi-refringence and straight extinction. Some of the garnets have cavities lined with a reddish-brown fibrous aggregate, which often forms concentric shells round a particle of iron-ore. In other crystals similar reddish-brown inclusions appear to be rutile. The felspars are all cloudy and show bent lamellae.

Similar pegmatites with garnet are common as intrusions in the charnockitic rocks of the coast zone, but the high proportion of garnet in the Hangili-ela rock is abnormal. As a rule the garnets are very sparsely distributed in the felspathic matrix.

The pegmatites of the two groups are younger than the charnockites and khondalites, and the red pegmatites, which traverse the Wanni gneisses are younger than this group as well. The sills of pegmatite of the Balangoda group though frequently interbanded with the charnockites may be seen in many cases to break across the foliation. Numerous transverse veins are also found. In the quarries at Kalu-bowila near Colombo the pegmatites enclose completely large blocks of charnockite. The remains of a sill of charnockite enclosed in zircon-pegmatite were also observed near Bibile.

Basic Dykes

Dolerite Dykes

Several basic dykes of doleritic character have been noted in the eastern and south-eastern parts of the island and a similar rock has been found on the west coast. The most important of these is the Kallodai or Gallodai dyke which crosses the Bibile-Batticaloa road at mile 57, and has been traced in a general NW-SE direction for 40 miles. The outcrop is marked by a line of rounded boulders which contrast strongly with the banded gneisses of the region. The width at the road-crossing is given as 95 yards by Parsons, who also observed metamorphism of the gneiss at the contact, and development of a coarse pink felspar-pyroxene rock. The full width and the boundaries of the rock cannot now be seen. The outcrop has been mapped by the Survey Department; according to legend it is the line of an ancient causeway. There is however no sign of any artificial construction along the few miles of the outcrop that I have examined.

A chain of hot springs of slightly mineralized water occurs along the line of the dyke south of Kallodai. There seems little doubt that

they are in some way connected with the dyke though this seems to belong to too early a date to allow of the supposition that they are a final phase of the igneous activity that produced the dyke itself.

Another outcrop of similar rock is seen near the junction of the coast road north of Batticaloa and the branch road to Kalkudah. The dyke lies near the Southern boundary of the pink Nilaveli-Kalkudah gneiss area. It appears to strike NE-SW but the outcrop is obscured by blown sand and alluvium. A third example cutting the khondalite series crosses the road half a mile east of Kantalai railway station on the Trincomalie line. It strikes a little to the east of north-east and thus cuts across the strike of the khondalites at a low angle. An identical rock at China Bay near Trincomalie may be a continuation of the Kantalai dyke. Another narrow dyke in biotite gneiss was noted at the mouth of the Uda Potana lagoon, between Kirinde and Kumane. This is on the prolongation of the line of the Kallodai dyke, but 50 miles distant from the last observed outcrop of that rock. The dyke strikes N 60° W across the NNW foliation of the gneiss.

Blocks of a similar rock were picked up on the dump of the Aluketiya mine near Migahatenna, 14 miles from the west coast of the Island. Its relations to the enclosing charnockite are not known.

The rocks are all typical dolerites. In the hand specimen they are coarse and even grained, the greenish-yellow felspar laths showing up plainly in the dark ground mass. The Gallodai rock contains abundant pyrite. Under the microscope they show some variations. The Kantalai and Kalkudah specimens are quite fresh. They are composed of intermatted laths of labradorite felspar, most of it in Carlsbad twins with pale brown augite, partly moulded on the felspar and the rest with good crystal outlines. The felspars also show lamellar albite or pericline twinning and combinations of the two, and some untwinned felspar is present. Iron-ore is abundant as magnetite and the dusty inclusions in the augite and felspar are probably magnetite. In the China Bay specimen, which is probably a continuation of the Kantalai dyke, the augites are very irregular in outline and a large proportion have the form of long laths. Some olivine is present and the proportion of micropegmatite is higher than usual. A few small patches of calcite are also seen (Plate XXI, Figs. 1 and 2).

In the Gallodai rock the felspars are all cloudy and the long laths often degenerate at one end into a fine-grained aggregate of felspar

and quartz granules, or are bordered by a zone of kelyphitic scales. Patches of micropegmatite are common. The augite shows alteration to biotite and some large cloudy crystals of dull green-brown hornblende are present. Pyrite is rather plentiful.

The narrow Udapotana dyke rock is distinguished by the occurrence of porphyritic plagioclase crystals in groups surrounded by micropegmatite. A single untwinned felspar surrounded by a zone of finely granular augite and felspar is also visible in the slide.

The Aluketiya specimens are of two kinds, a coarser grained typical dolerite and a very fine-grained black rock in which the crystalline structure is hardly discernible. The body of the rock consists of slender intermatted felspar laths, many of them enclosed poikilitically in augite and olivine, which is present in small proportion. The minerals are all perfectly fresh and no micropegmatite is seen. The fine-grained variety evidently represents the chilled margin of the dyke. It is a microcrystalline mass of opaque iron-ore, clear felspar and augite with many minute laths of felspar lying parallel to one direction and numerous tiny phenocrysts of olivine. The proportion of opaque minerals is variable, the slide being divided into a light and a dark band, with a transverse band cutting both. Inside the transverse band the felspar laths lie parallel to its edges. The ground mass round the olivine shows zoning, the proportion of iron-ore diminishing as the edge of the phenocryst is approached (Plate XI, Fig. 3).

The dykes agree in petrological character with the augite-diorite dykes of the Salem district, described by Holland (*M. G. S. I.*, Vol. XXX, p. 131). These are generally regarded, according to this author, as the dyke-representatives of lava-flows of Cuddapah age. Similar dykes with a wider range of composition were observed in the North Arcot district (*R. G. S. I.*, Vol. LXVI, p. 114). They are here dated by Dr. Iyer as younger than the newer pink granites which correspond closely with the Wanni gneisses of Ceylon.

Peridotite Dyke

A highly serpentinized rock, which seems to be the product of weathering of an ultra-basic peridotite, is found as a sill 8 feet wide amongst charnockites and khondalites in a small stream on the road from Hatton to Annfield estate. In its present state the rock is a pale green serpentine with a few glittering scales visible in the mass and a border of dark green compact serpentine which also traverses the body of the rock as veins. Some white mica and calcite are found along the margins, and knots of white mica crystals are common in the soil of the river bank. Under the microscope the rock

is shown to consist of fibrous serpentine after olivine; the outlines of the original crystals are visible and many unaltered fragments remain. In addition the rock contains abundance of irregularly shaped granules of an isotropic, colourless mineral of high relief, which I take to be spinel, though the grains are sometimes elongated and none show the characteristic crystal form. A little calcite is present on one side (Plate XXI, Fig. 4).

Pyroxene-scapolite Dykes

A narrow dyke of unusual type could formerly be seen in the Public Works Department quarry about a mile from the north shore of the Maha Lewaya at Hambantota. The dyke has a width of 3 to 6 inches and cuts irregularly across the foliation of the normal biotite-gneiss of the area. In hand specimen it is a dull grey to nearly black dense rock with coarser bands, and numerous cavities lined with quartz, calcite, and scapolite crystals and some pyrite. It consists of a fine even grained aggregate of pyroxene and scapolite, with bands composed almost entirely of scapolite with rare augite and sphene. These bands consists of interlocking crystals of scapolite, with all orientations. The borders of the crystals are clear but the centres are crowded with acicular inclusions, which appear to be rutile needles, arranged parallel to the crystal axis. Some biotite and uralitic hornblende are also present. The pyroxene is mainly augite in roughly equal-sized allotriomorphic grains, of a dull green colour and markedly pleochroic. It is intergrown with some diopside and with sphene.

The rock shows numerous patches of calcite in which are embedded hypidiomorphic pyroxene and pyrite.

The contact with the gneiss is fairly sharp. There is generally a selvedge of quartz in thin lenticles along the wall. Where this is absent the scapolite has penetrated the wall rock for a very short distance (Plate XXII, Fig. 2).

A narrow vein of diopside-scapolite rock was also seen traversing quartzite of the khondalite series at Hangili-ela. The rock is composed of pyroxene with subordinate scapolite. The pyroxene is colourless in thin section and the scapolite shows no inclusions.

It is remarkable that in close proximity to each of these dykes there are narrow dykes of basic garnet-pyroxene-plagioclase rocks indistinguishable from some members of the charnockite series. At Hangili-ela the transverse dykes may actually be seen to branch off

from sills of basic charnockite interbanded with the khondalites. The diopside-scapolite dyke is only a few yards distant, but it cannot be traced to its junction with any sill. Limestone occurs amongst the khondalites and it is possible that the charnockite magma has absorbed lime and crystallized as a hybrid pyroxene-scapolite rock similar to the contact-rocks which are so wide-spread in Ceylon, but as a transverse vein penetrating the schists instead of as a zone at the contact of limestone and charnockite. Neither limestone nor charnockite has however been observed near the Hambantota dykes.

Coomaraswamy (*Geological Magazine*, 1905, August) described certain basic dykes observed by him near Mimure, on the eastern flank of the hill-country. I have not seen the actual paper but in his Progress Report No. 16 of July, 1906, he refers to the paper and describes one of the dykes. It has a width of 6 feet, follows the foliation planes, and is composed on the outside almost entirely of grey pyroxene with a central portion consisting of coarse orthoclase, idiomorphic pyroxene up to 6 inches in length and large idiomorphic sphenes up to 2 inches long, and some zircon.

Similar large prisms of pyroxene up to a foot in length and associated with rhombs of calcite were found in a graphite mine at Ragedara in the North-western Province. I was unable to see the mode of occurrence, but it seems probably that they were derived from a similar vein. The pyroxene prisms were highly altered externally, with the formation of zones of quartz and calcite.

Pyroxene-scapolite Rocks of Galle

An assemblage of scapolite bearing rocks and their associates from the surroundings of Galle port was described by Coomaraswamy (*Q. J. G. S.*, Vol. LVII, 1902, p. 680-689). They comprise (*a*) pyroxene-sphene-scapolite rocks, exactly like the Hambantota intrusive (*b*) pyroxene-scapolite-wollastonite rocks with subordinate felspar and quartz, which pass over by gradual increase of the quartz and felspar and diminution of pyroxene into (*c*) coarse grained quartz-felspar rocks of granitoid aspect. The acid types are of somewhat later origin than the basic and though generally interbanded behave on the whole in an intrusive manner to them. Later dykes including acid rocks with a little augite, and coarse wollastonite-orthoclase-quartz-pegmatites cross the foliation. The author concludes that the wollastonite and scapolite are original minerals and attributes the richness in lime either to absorption of limestone by the invading magma or to the original character of the magma.

Occurrences of similar rocks not far from Galle are recorded by Coomaraswamy at Pittiwela on the coast and in a graphite mine near Baddegama, where wollastonite was recorded. Both of these are according to my observations isolated in the great charnockite mass of the south-west of the island.

A similar rock consisting of diopside and scapolite in about equal proportions with subordinate quartz and calcite and some sphene, was picked up by me on the dumps of an abandoned graphite mine at Nakkawatta, midway between Narammala and Dandegamuwa in the southern part of the North-Western Province. The locality is 120 miles north of Galle. It lies on one of the northern protrusions of the charnockites into the Tonigala gneiss area. The diopside-scapolite rock was associated with a coarse quartz-felspar-graphite rock and a normal biotite-pegmatite. The mutual relations of the three rocks could not be observed.

It is evident that the rocks are not confined to the Galle area. It is also clear that they are not very extensively developed in any part of the Island. The coastal zone between Matara and Moratuwa has been mapped tentatively by Adams as occupied by the Galle group. The numerous exposures in this zone which I have examined are all varieties of charnockite with no peculiarities which would justify their separation from the other rocks of the series. The Galle lime-bearing rocks themselves are of limited extension, and occur outside the area. Related types are found at Hambantota and again in the north-central part of the island. The coastal zone should therefore be mapped as charnockite.

The occurrence at Hambantota of isolated vein-like rocks consisting of pyroxene and scapolite supports the view that the Galle rocks are residuals of the charnockite magma which have invaded the already consolidated rocks. The occurrence of calcite in the Tonigala pegmatites and gneisses leads to a similar conclusion and brings out a point of similarity between the two intrusives.

An intrusive rock of a different nature unrelated either to the Galle rocks or to the pegmatites which are so common in the island, was observed at Ahungala on the coast 22 miles north of Galle. It is a well-defined dyke with parallel sides, 6 feet wide, and crossing the foliation of the charnockite nearly at right angles, the strike being N 60° E. In appearance it is a moderately fine-grained greyish yellow rock with numerous porphyritic pink felspars up to 8 mm. long with a felspathic ground mass showing a little dark hornblende. It is composed of orthoclase and plagioclase, with quartz in long ribbons

or rare rounded blebs, but not definitely banded. The porphylitic crystals are orthoclase; they contain prisms and rounded bodies of quartz, and also hornblende and mica and perthitic albite. The hornblende is dark-green to yellowish green and often hypidiomorphic. Calcite with good crystal outlines against the felspar is common. The accessory minerals are zircon, which is very abundant, apatite, and sphene. No other examples of this variety have been found. The occurrence of calcite suggests that it belongs to the Galle group of intrusives.

STRUCTURE OF THE ISLAND

In the parts of the island occupied by the khondalites, charnockites, and Wanni gneisses the strike of the gneisses and schists follows a regular curve. The central hill-zone is a syncline with minor folds, the axis being tilted to the north, so that along the southern escarpment the schists dip inward towards the centre of the mountain mass.

On the eastern side the schists terminate in long escarpments facing east with a westerly dip. On the west the boundary is less regular. In the Adams Peak range the dips are towards the synclinal trough, but the last exposures of unmistakeable khondalites seen, in the lower ground further to the west, dip to the west. There is thus a sharp fold near the western side of the khondalite area.

North of the hill-zone the strike of the khondalites is for some distance meridional. It then swings round rather rapidly to NE at Trincomalie, where the band runs out to sea.

The strike of the khondalites of Southern India, as pointed out to me by Dr. Fermor, swings round rapidly from NE to SE near the mouth of the Kistna river and the band of schists runs out to sea there. It seems very probable that these rocks in Ceylon and India belong to one recurved band.

The strike of the charnockites of the south-west sector follows that of the schists, veering gradually from WNW at Tangalle where the beds run out to sea, to NNW near Colombo. North of this the strike continues in the Wanni gneiss area as a sinuous curve which veers as far as NNE but returns to N-S in the most northly exposures seen in the island.

The strike of the gneisses along the west coast of India north of Cape Comorin is given by Bruce Foote as NW. The character of the gneisses of this area is not stated and it is uncertain whether they are related to the charnockites or to the Wanni gneisses.

The observed strike of the rocks in Ceylon is indicated on the map by red lines. It will be noted that these do not coincide with those shown on Adams' map. I am also unable to agree with this author on other details. In particular the delineation of the limestone bands appears to me arbitrary. I can find no confirmation after the most careful inquiry of the existence of a band of limestone at Morawaka, near Kegalle, which Adams describes as the most westerly exposure in the Island. There is no limestone in or near the village itself but about 3½ miles to the south a small mass of limestone was formerly quarried in Hulumbuwa village. The limestone has the form of an irregularly ramifying mass about 100 feet long in its maximum dimension. It consists of pure calcite and has more the appearance of a segregation within a mass of a basic micaceous charnockite than a sedimentary band. Similar segregations of calcite within charnockite have been seen in other places.

The prolongation of this band to the NNW is not supported by any evidence. It was not observed by Wayland in the neighbourhood of Tabbowa, an area which was surveyed in some detail. On the other hand there are in the north-western part of the island, particularly near Galgamuwa and Eppawela, several strong outcrops of marble, any of which might with equal plausibility have been linked up with the Morawaka band if it existed, but these are not mapped by Adams.

The course of the great Kandy-Matale band of marble again is incorrectly shown. It can be seen to cross to the eastward of the road between Naula and Dambulla and trend in the direction of Sigiriya. It is undoubtedly a branch of the great Sigiriya exposure. North of Nalande it bends first east and then west, crossing the road near Habarana, beyond which it has not been traced. It certainly does not continue to Mihintale as shown by Adams. The limestone there, if it is to be regarded as a sedimentary rock, which is uncertain, is more likely a prolongation of the sedimentary Kunchuttu-Kirigollewa band to the NE of Mihintale.

For similar reasons I am unable to agree with Adams on the mapping of the limestone bands round the southern and eastern flanks of the hill-country. There are at least two parallel bands on the southern escarpment. Adams' map shows only one, which occupies the observed position sometimes of the upper band and sometimes of the lower. A number of outcrops have been observed by me both in the hill-zone and in the lower country to the north. Until these folded areas have been carefully mapped, it is unsafe to attempt to correlate them.

The strike of the Bintenne gneisses of the south-eastern sector is very irregular, and I have not been able to discover the extreme simplicity of the strike-lines figured by Adams. On the contrary the majority of the strike-directions which I have observed in this area do not conform to those lines. The rocks dip at low angles with gentle folds along more than one system of axes. I have not been able to trace the system of folding: it appears however to have no relation to that of the other rocks of the island, and to belong to an earlier epoch.

A generalized section from south-west to north-east through the central part of the island is shown in Fig. 6.

CHARNOCKITES   KHONDALITES   DIAGRAMMATIC SECTION ACROSS CENTRAL CEYLON   BIOTITE GNEISS.
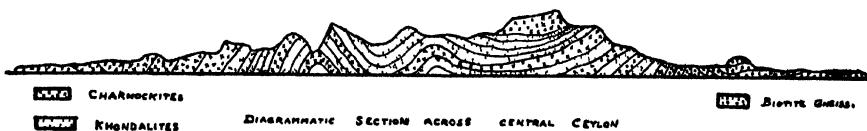
Fig. 6. Diagrammatic section across Central Ceylon.

ECONOMIC MINERALS

Graphite

Graphite, or plumbago, as it is almost invariably called locally, occurs in Ceylon disseminated in the schists and marbles of the khondalite series, and in some of the leptynites, and also as vein-deposits. The latter provide the graphite of commerce.

The vein-deposits comprise (1) fissures filled with graphite alone, either parallel or transverse to the foliation of the gneisses (2) pegmatitic veins in which graphite plays the part of an accessory mineral but locally increases in proportion till it is the principal constituent of the rock (3) lenticular segregations in a highly sheared acid garnetiferous gneiss, which is possibly a crushed pegmatite. The three types of deposit are only morphologically distinct. They may all occur in the same mine, and one form may graduate into another.

The true vein-deposits occupy fissures in the charnockitic rocks or lie along the junction of two bands. The fissures are often branching, blocks of the country rock being sometimes completely encircled by graphite-filled fissures, and may even form a stock-work. The groups of transverse veins are connected with a longitudinal vein, which is usually of minor importance as far as the yield of graphite is concerned. The fissures may be mere stringers; the workable veins have a width from a few inches up to 3 feet. Individual veins vary greatly in width, sometimes swelling out into wide pockets.

The graphite may extend from wall to wall of the fissure in long flakes or needles or as a finely crystalline aggregate. Many veins show a composite structure, coarsely crystalline and fine material, or successive bands of long flakes, alternating symmetrically. Thin stringers or quartz may also occur in a vein. In the larger pockets the graphite blocks are irregularly crystallized and often include quartz, orthoclase, and pyrite. In some veins the graphite has a slaty structure as the result of movement of the walls.

The graphite crystals penetrate the country rock only for a short distance, but isolated flakes of the mineral are found an inch or two away from the wall. Where a vein penetrates charnockite the wall rock may be seen to be altered near the contact. Hypersthene is converted into cloudy brown hornblende and calcite is deposited in the rock, either as interstitial crystals or as veinlets projecting from the graphite vein. Penetration by graphite and deposition of calcite seem to be more extensive in the crushed acid garnetiferous rocks which frequently border the veins than in the charnockites. Scapolite is frequently intergrown with graphite near the edge of a vein and deposited in the country rock on the wall.

Pyrite is a common mineral in the veins, sometimes so intimately intergrown as to make the separation of the two minerals very difficult. More often the pyrite crystals are coarse and easy to separate. Apatite is also common and molybdenite has been recorded. Calcite is nearly always present, in all dimensions from microscopic flakes to well-crystallized rhombs 2 inches in length. Coomaraswamy (Administration Report, 1905, p. 3) states that the association of the two minerals is rare. My more extended observations lead to the opposite conclusion.

In many of the vein systems the filling of the fissures may be nearly pure graphite in one section and pegmatitic material with more or less graphite in another. The transition is gradual, quartz and othoclase increasing in proportion until graphite becomes an accessory mineral in a graphite-pegmatite. The graphite in these end-rocks is mainly disseminated in the quartz, in the form of rosettes or flakes, and is nearly always associated with pyrite. Locally the veins are enriched in graphite and may be workable for part of their length.

The graphite deposits of the Galle district have the form of lenticular bodies in bands of a crushed graphite-bearing acid rock, which is a crushed pegmatite of the type described above. Many of them are practically graphite-schists with varying proportions of the mineral, which is separated from the quartz and felspar by a washing process.

The workable deposits in this area are extremely irregular in form. When a segregation of graphite or an enrichment of the pegmatite is found it is worked until the lens is exhausted or until the pegmatite becomes too poor in graphite to repay extraction, and the mine is then abandoned. The fissure-veins, on the other hand, have been worked to 1,700 feet below ground level.

Distribution of Vein-graphite

The principal mines are situated on well-defined belts following the strike of the gneisses. The belts are commonly less than a mile in width but they extend for several miles along the strike. Successive groups of mines may lie along the same line of strike and it is possible that future prospecting will show some of the belts to be continuous for over 50 miles. In the Galle district outcrops are so numerous that no definite linear disposition can be made out.

The position of the principal graphite-producing zones is shown on the map.

The graphite mines are most numerous in the great charnockite area of the south-west of the island. A few mines have been worked in the hill-zone where rocks of the khondalite series are of equal importance with the charnockites. The Laxapana mine, a few miles east of Adam's Peak, was at one time an important producer. The veins worked were in charnockite and pinched out when they entered the adjacent quartzite. Several small mines have also been worked in the Badulla district.

The mines of the very important Ragedara-Maduragoda group are worked on transverse veins in a lenticular mass of sheared charnockite and garnetiferous leptynite enclosed in gneisses of the Kadugannawa group. In the most northerly mine known in the island, 5 miles east of Vavuniya, the vein was of the pegmatitic type with large masses of graphite in glassy quartz and felspar. The area surrounding it is mainly occupied by gneisses of the Tonigala type, but charnockites are also found. The actual country rock of the vein was not seen.

The constant association of graphite with rocks of the charnockite series points to some genetic relation between the two. It is especially noticeable in Ceylon (1) that no graphite veins are known to exist in the Bintenne gneiss area, where charnockitic rocks are extremely rare and (2) that the graphite-bearing zones die out near the boundary between the charnockites and the younger Wanni gneisses, and, with the possible exception of the Vavuniya vein, do not penetrate the younger gneisses.

Origin of the Graphite

The graphite veins of Ceylon, as distinguished from the graphite-bearing schists and marbles of the khondalite series, occur mainly in the great charnockite area of the south-west. A few veins are found in the hill-country, a region where charnockites and khondalitic rocks alternate, but only in areas where the charnockite intrusions are well developed. No veins are found in the older Bintenne gneisses, and if the one doubtful occurrence near Vavuniya is excepted, none traverse the younger Wanni gneisses.

In South India graphite veins similar to those of Ceylon occur in an area of charnockites and leptynites, which according to Tipper is geologically similar to Ceylon (*R. G. S. I.*, Vol. XLIV, p. 186). No mention is made of graphite veins in the great charnockite area surveyed by Holland. Walker recorded occurrences of graphite (*a*) in khondalite and (*b*) in biotite-gneiss, in the Kalahandi State (*M. G. S. I.*, Vol. XXIII, p. 16). In the records of Mineral Production for 1931 (*R. G. S. I.*, Vol. LXVI, p. 303) an output of graphite from the Kistna district of Madras is recorded. This lies on the north-eastern extremity of the charnockite area and near the south-west end of the band of khondalites and charnockites of the Kalahandi State.

The graphite vein deposits of Ceylon are undoubtedly the result of the filling of fissures in charnockite and associated crushed acid rocks by intrusions of pegmatitic type and in extreme cases by the graphite which in some form accompanied them. The charnockite series in Ceylon shows the effects of shearing movements which have developed micaceous varieties and leptynites differing considerably in character from the rocks of the type area in India. The graphite veins occur in zones in which the shearing has been most intense.

Holland (*G. M. S. I.*, Vol. XXVIII, p. 152) records the occurrence of graphite as an original mineral in a basic member of the charnockite series. Apart from its occurrence in the wall-rocks of veins graphite has been observed in a few instances as an original mineral in the Ceylon charnockites but only in about 2 per cent. of the large number of specimens examined. It is therefore by no means common.

On the other hand it is possible that the carbon of the charnockite is derived from carbonaceous rocks which have been absorbed by the invading charnockite magma. The graphite of the khondalites and associated marbles may be considered as the product of metamorphism of carbonaceous material in shales and limestones. Some specimens of khondalite are very rich in graphite, but they appear to be rare and

of no great extent.   No khondalites have been identified in the south-
western portion of the island where graphite veins are most frequent.
The last observed outcrops of the khondalites on the west side of the
hill-zone dip under the charnockite.   Isolated short bands of granular
quartz rock are found amongst the charnockites and also inclusions of
calcite.   These may represent undigested fragments of rocks of the
khondalite series or differentiates from the hybrid magma formed by
solution of the older rocks.   If graphitic schists with a carbon content
equal to that of some of the varieties observed in the hill-country have
been dissolved by the charnockite, enough carbon may have been
supplied to it to provide the material of the subsequently formed
graphite veins.   There is however insufficient evidence of the existence
of such carbonaceous schists, and this view of the origin of the graphite
in the charnockites requires confirmation.

Precious Stones

The precious stones found in Ceylon have been famous from the
earliest times and are still produced on a large scale.   The most impor-
tant are the varieties of corundum, chiefly sapphires, and other coloured
varieties to which various names have been given.   In addition there
are found beryl (aquamarine), chrysoberyl, zircon, tourmaline, and
spinel of several shades, garnet, topaz, and moonstone.   Some coloured
varieties of quartz, including amethyst and citrine quartz are also cut
as semi-precious stones.

With the exception of moonstone practically all the gems are obtained
from alluvial gravels : some however have been found in eluvial mater-
ial on hill-sides.   The gravels are mainly those of the great strike
valleys of the south-west of the island.   The smaller hill streams are
often worked successfully, but the upper courses of the larger tôrren-
tial streams are generally so much encumbered by large boulders that
the bottom or pay-gravel cannot be reached.

The major tributaries of the rivers flow in wide flat-bottomed strike
valleys, the stream itself meandering through a wide flood-plain.   The
gem-bearing gravel underlies a varying thickness of alluvium, capped
by several feet of clay, with alternations of gravel, sand, and clay down
to the bed-rock, which is almost always thoroughly decomposed and
soft.   The pay-gravel rests on the bed-rock, though in rare instances
one or more streaks of pay-gravel may be intercalated in the alluvium,
the bulk of which is however barren.   The pay-gravel does not form
a continuous sheet over the flood-plain.   Rich patches occur here and
there, with wide intervening barren stretches.   These rich patches re-
present either the areas down-stream from some underlying gem-bearing

rock which was at one time eroded by the stream, or re-sorted material from some lateral tributary which dropped its load at that point when the wall of the valley occupied that particular position. They generally have very well defined limits and a prospecting pit sunk a few yards outside the rich patch may give completely discouraging results. When however a good find is made it is practically certain that other good stones will be found close to it.

Terrace-gravels of the larger streams have occasionally been successfully worked. Some of these are of such ancient date that the rocks in them have been almost entirely lateritized. The quartz pebbles and gem-stones remain unaltered except for a marked corrosion of the surface, which contrasts strongly with the smooth or polished surface of the stones in the younger deposits.

The depth to the pay-gravel varies from five to thirty feet. The shallower deposits generally occupy the heads of the valleys. In exceptional instances the pay-gravel lies at a much greater depth. In the Botiyatenna valley, at the head of the Rakwana-ganga, gem gravels were worked at a depth of over 100 feet below ground level. The gravels were laid down by the river and subsequently covered by a chaotic accumulation of boulders from land-slips on either side.

The distribution of the gemming-fields is shown on the map at the end of this memoir (Plate XXIII). The principal deposits occur along the foot of the main mountain mass in the western part of the Sabaragamuwa Province and the adjoining part of the Western and Southern Provinces. At its northern end the boundary is very sharply defined, and the western boundary is also fairly sharp. At the southern end sporadic deposits occur, becoming gradually more widely separated towards the south-east. The eastern boundary is equally indefinite. Gem-stones have been found to the east of the Adam's Peak range, particularly in the Maskeliya district, but no fields equal in importance to those of the Ratnapura district, where gem-stones may be found in practically every stream-bed, exist outside the area defined on the map (Plate XXIII).

There is some variation in the nature of the minerals found in different parts of the field. Roughly speaking sapphires are more plentiful in the northern section, from Rakwana-Pelmadulla to Avisawella, while chrysoberyl and varieties of zircon are more conspicuous in the southern. The latter are however found throughout the area and one remarkable find of sapphires was made at Aparekka, north of Matara.

Sporadic occurrences have been noted outside the main area at Nuwara Eliya and on the Horton Plains, and still further to the east near Badulla. A few fragments of coloured clear corundum were

found in the Menik-ganga, near Kataragama : these were however rolled pebbles, which quite probably had travelled a long distance. Similar rolled pebbles are found in old gravels of the Kelani and Kalu-ganga. Chrysoberyl is widely distributed in the mountain-zone of the Central Province, but good finds are rare. Some good aquamarines were also found in a pegmatite vein near Matale and large opaque beryl in a similar vein near Kandy. Garnets of good colour are also found in the Dumbara valley near Kandy.

Source of the Gem-minerals

Corundum has been found in Ceylon in rocks of the khondalite series (see p. 123) and also in Kandy district in a narrow band of felspathic granulite (Coomaraswamy, *Geological Magazine*, 1903, 348-50). The crystals from the khondalites are tabular and of a red or purple colour and opaque. The crystals described by Coomaraswamy were hexagonal prisms of a dull-greenish colour and also opaque. No clear corundum has been found in association with the rocks described, and the precious corundum of the alluvial gravels has evidently a different origin.

Transparent precious corundum was found by me in a pegmatite vein in Aparekka village near Matara in the Southern Province. The pegmatite was a flat sill intercalated in decomposed granulites, and was itself highly decomposed. It appeared to be a normal biotite-pegmatite, but was characterized by the existence of a line of boulders of brown chalcedony along the outcrop. Some of these were of large dimensions. The chalcedony was not found within the pegmatite a few feet from the outcrop, and is evidently of secondary origin.

The corundum was in the form of hexagonal prisms with terminal pyramids measuring up to an inch in length. The larger crystals were traversed by numerous cracks and broke up into small fragments while being washed out of the decomposed rock. They were associated with felspar and biotite in a narrow zone bordering a thick felspar lens near the foot-wall. The corundum was concentrated in a long narrow streak, which yielded several pounds of the mineral. Wherever tested the vein yielded a few crystals, but extensive prospecting failed to discover a second rich patch. The alluvial material below the outcrop was washed by the owners of the land and yielded a large quantity of corundum, including some very valuable stones. A similar rich deposit was found in the alluvium of a small valley a short distance away.

Pegmatite veins showing a similar line of chalcedony boulders along the outcrop were prospected in other parts of the district, and yielded some minute sapphires in one instance, and opaque corundum in others, but no gem-stones.

Another occurrence of gem-corundum *in situ* was discovered on the edge of the Horton Plains. The corundum was found in a lens of decomposed felspar apparently connected with a pegmatite vein. The crystals had the characteristic barrel shape, but broke into fragments when detached. They were of a pale blue colour and generally cloudy, but one or two fragments were suitable for cutting as gems.

The source of the gem-corundum of the Ratnapura district has not been discovered, though extensive prospecting operations have been carried out in search of it. It is noteworthy that the best stones are usually concentrated in very rich patches of gravel separated by barren areas. It is therefore probable that they occur, like the Aparekka sapphires, in dense groups in parts of a pegmatitic vein, with long intervals between the rich groups.

There is no evidence that the gem-corundum is derived from the crystalline limestones. Marbles are very rare in the gemming area, and corundum is equally rare in districts where the marbles reach their greatest development.

Of the other precious stones beryl, chrysoberyl, zircon, tourmaline, and topaz have all been found in pegmatite veins, their usual habitat. Small spinels are often found in concentrates from decomposed pegmatite: they are also common in association with mica in segregations sometimes near limestone bands, but often apart from them.

Amethyst and yellow or colourless quartz are found sometimes as very large crystal aggregates on the outcrop of pegmatite veins in the Kandy district. The smaller crystals are common near the large quartz veins which are common throughout the island.

Garnet is widely distributed in the granulites and pegmatites and every alluvial gravel yields a large amount of this mineral. The semi-precious stones include pyrope, almandine, spessartite, and rhodolite. The larger fragments are derived from large crystals which occur in certain rocks which appear to be pegmatites, though their true nature is uncertain. The garnets occur in these as crystals, or groups of crystals forming nodules, several inches in diameter. These are traversed by numerous cracks and break up into fragments when liberated from the rock.

The moonstone of Ceylon is found in bands of a sheared quartz-orthoclase rock probably an acid phase of a pegmatite. Formerly the only occurrences known were all in the neighbourhood of Kandy, but subsequently a band of similar rock was found at Weragoda, on the west coast, near Ambalangoda. The orthoclase individuals may be a foot in length but they are traversed by numerous cleavage cracks, and

an unflawed stone over an inch in its longest dimension is comparatively rare. The Weragoda moonstones showed a beautiful blue opalescence, whereas the stones from round Kandy were only faintly blue. Both deposits are now apparently worked out.

Mica

Mica is found in commercial qualities (1) in contact zones on the borders of limestones (2) in pegmatites. The limestone contact deposits are found chiefly on the edges of the Kandy-Matale limestone band, and are occasionally worked on a small scale. The mica is a greenish-yellow or light brown phlogopite. It occurs as large and small crystals in groups associated with pale yellowish-green diopside, calcite, and orthoclase. The crystals often show perfect form. They may contain lath shaped inclusions between the foliae and are frequently bent.

These mica-diopside bodies have a lenticular form and frequently pass over into true mica-veins, which penetrate the adjacent rocks. The veins are inconstant and taper out or degenerate into finely crystalline mica within a short distance.

Muscovite, phlogopite, and biotite are all found in large crystals in pegmatite veins. The mode of occurrence appears to be the same as that of the Indian mica, but the Ceylon deposits have little commercial importance. Good veins have been worked in the past near Balangoda and Haldumulla, and specimens of mica of commercial size have been collected in many parts of the island. Attempts to work the deposits have however invariably ended in failure mainly on account of the low proportion of sound merchantable mica produced from the crude mineral.

The pegmatite veins which were worked at the two places named undoubtedly belonged to the Balangoda group. Many of the other mica-bearing veins were not actually examined, or were not exposed well enough to allow their relations to be determined. The mica forms crystals or groups of crystals between the felspar individuals or completely enclosed in felspar. The larger crystals and groups are separated by barren portions of the vein in which only small or flawed mica crystals are found.

Thorianite

The mineral thorianite was at one time mined in commercial quantity from alluvial deposits in small streams in the Ratnapura district and the northern part of the Galle district. The mineral consists of the oxides of thorium and uranium, with lead, iron, zirconium, and rare earths. The proportion of thorium oxide varies from 60 to 75 per cent., and of uranoso-uranic oxide from 8 to 25 per cent. The mineral is

derived from pegmatite veins of the Balangoda group. It is found in gravels, associated with thorite, monazite, fergusonite, aeschynite, and zirkelite, also zircon and tourmaline, all no doubt derived from similar veins. It crystallizes in the cubic system and is generally found in the alluvial deposits as cubes mainly small, but rarely up to one inch, or interpenetration twins, showing little rounding of the edges.

At Neluwa in the Galle district a small quantity was produced from the decomposed outcrop of a wide pegmatite vein, but the yield was too small to repay the cost of extraction. The vein also yielded small crystals of chrysoberyl.

A systematic examination of river and valley gravels in the Ratnapura district was made in search of placers of the mineral. Although patches of gravel containing thorianite were frequently met with in the river-beds themselves or under their flood plains no extensive deposit suitable for commercial exploitation was found. The thorianite-bearing gravel was not evenly distributed over the valley floor, but was limited to small areas in which a few unworn crystals were found A large number of pegmatites were tested in the Ratnapura district and elsewhere by washing material from the decomposed outcrops. Monazite was almost invariably found in the concentrate, but thorianite was rare, and only in one of the veins out of some hundreds tested was any appreciable amount present. It would appear therefore that the mineral is too sparsely distributed in the parent rock to allow of the formation of extensive workable placers even under the most favourable conditions. The rich deposits which were actually worked were all of small extent and in close proximity to some abnormally rich pegmatite.

Ilmenite, Monazite, and Zircon Sands

Natural concentrates of ilmenite, monazite, and zircon with some garnet are formed by wave-action on the seabeach almost everywhere along the coast of Ceylon, but it is only locally that the deposits are sufficiently extensive to have any practical importance.

The minerals are all common as accessories in the crystalline rocks. Ilmenite and zircon are common in all the intrusive rocks: monazite occurs in notable proportion in the Wanni gneisses, and is a conspicuous accessory mineral in the younger pegmatites: it is also present in the charnockitic rocks, but in very small proportion.

The concentrates are in general formed as narrow bands for a short distance below high-water mark. Their formation is however in most instances seasonal, and a change in the prevalent wind, with an accompanying change in the long-shore current, may obliterate an existing band of concentrate or initiate the formation of a new one on a beach

where the heavy minerals are uniformly mixed with quartz sand. The obliteration of an existing concentrate is sometimes due to the deposit above it of a layer of quartz sand drifting in from the next bay or to the pushing up of the quartz sand from below low-water mark. Most beaches when dug into show an alternation of layers of light and dark sand.

Extensive deposits of ' black sand ' containing the three minerals enumerated are found at the mouths of the principal rivers of the west coast. The minerals have evidently been brought down from inland by the rivers and added to the accumulations derived from erosion of the coast. On the east coast two deposits of much greater bulk and not connected with existing rivers have been examined. At Pulmoddai 40 miles north of Trincomalie, a ' black sand ' deposit occurs as an old beach about 4 feet above sea-level and composed almost entirely of ilmenite and zircon. It extends for a distance of two miles, with a width of 150 feet. The seaward face has a gentle slope down to low-water mark and the ' black sand ' has been found to extend for some distance out to sea. North of this old beach, ' black sand ' covers the existing beach for another three miles, to the mouth of the Kokkilai lagoon.

The thickness of sand in the old beach is over 5 feet. It rests on a shelving surface of reddish sandy clay and is covered on its landward side by dunes of red sand containing much ' black sand '. The beach does not extend inland beyond the toe of the dunes. The country inland is an alluvial plain partly covered with blown sand.

The ' black sand ' consists of about 75 per cent. ilmenite and 25 per cent. zircon in small crystals. The ilmenite also is noticeably finer in grain than the black sands of the west coast. Magnetite and monazite are in very small proportion, though the Wanni gneisses which are exposed along the coast to the south are rich in these accessory minerals.

The main part of the deposit on the old beach is estimated to contain over two million tons of black sand, and an equal quantity probably exists along the beach to the north and under the sea. The only other deposit at all comparable is that at Tirukkovil described later. No satisfactory explanation of the origin of this enormous mass of concentrate can be offered. The country rock inland, and a short distance to the south of Pulmoddai is a pink gneiss rich in magnetite with comparatively little ilmenite. The ilmenite therefore is not of local origin. The thick deposit of sand is bounded on the south by a high headland and extends as far as a low rocky promontory which projects only a

short distance beyond the general line of the coast. The concentration is possibly the result of current action in the bight, but no clear evidence of this can be given.

The Tirukkovil deposit is of less importance. It borders the coast for three miles from the site of the old Tirukkovil resthouse, 45 miles south of Batticaloa. The deposit is frequently covered by quartz-sand. Its mode of origin is clear. The coast-line here is evidently receding. A sand-reef, marking the site of an old spit, runs out from the shore at a slight angle for two or three miles. During the south-west monsoon there is a strong current between the sand-reef and the shore. This has cut back the shore-line rapidly, carrying off the quartz-sand and concentrating the heavy minerals.

Monazite Sand

Monazite is invariably found as a constituent of the black sands of the west coast. The proportion of monazite to ilmenite rarely rises over 2 per cent. Narrow streaks of richer concentrate are sometimes formed at the upper limit of wave-action on a steep beach, but they are impermanent. Ilmenite sand containing a higher percentage of monazite is found in a bay at Kaikawala village on the west coast, four miles south of Bentota, and a small amount of rich concentrate amongst the rocks off Kudremalai point, south of Mannar.

The Kaikawala deposit extends along the shore of a shallow bay between two headlands half a mile apart. The headlands are joined by a narrow beach-bar of the ordinary type which continues to the north for over two miles. The bar enclosed a system of lagoons now silted up and converted into swamps. The beach-bar has been driven inland and now rests on the lagoon beds, which are occasionally exposed on the beach. The monazite and ilmenite are exposed as good concentrates on the beach at certain seasons, at the period of change of monsoon. The concentrate is never more than a few inches thick but some streaks of it contain as much as 40 per cent. of monazite. The average is about 15 per cent.

The monazite is derived originally from local pegmatite veins, one of which was found to contain the mineral in fairly large crystals. The heavy and resistant minerals accumulated in the depression now occupied by lagoon deposits. The minerals are set free originally by erosion of the lagoon deposits, and partly driven up with the quartz-sand to form the beach-bar. The seasonal deposits of concentrate are produced by the re-sorting of the beach-sands.

The concentrates formed in the bay to the north of Kaikawala also show about 5 per cent. of monazite. The whole deposit was estimated

to contain only three or four hundred tons of monazite. It was worked on a commercial scale until the fall in price of monazite made operations unprofitable.

The black sand consists mainly of ilmenite, with garnet, monazite, and zircon in varying proportion and small quantites of spinel, rutile, tourmaline, and also thorianite and baddeleyite in minute rounded grains.

The only other deposit of monazite sand of commercial importance is found at Kudremalai, forty miles south of Mannar. The beach here is bordered by rocks of the Miocene sedimentary series which form a low cliff about ten feet above water-level and deeply indented. The concentrate lies at the head of the little beaches in the indentations. The total quantity of the mineral is not more than a hundred tons. Towards Marichchakaddai the coast is low and the beach is covered with an ilmenite concentrate poor in monazite.

The cliffs at Kudremalai are capped by red sandy beds containing both ilmenite and monazite and similar to the Warkalli rocks, which cap the cliffs near Kolachel in Travancore, where extensive deposits of ilmenite and monazite have been worked for some years. The area inland is probably occupied by gneisses of Tonigala type, which all contain a small amount of monazite. This has accumulated in the Kudremalai beds derived from them. The monazite of the beach-concentrate is the product of erosion of these younger sediments.
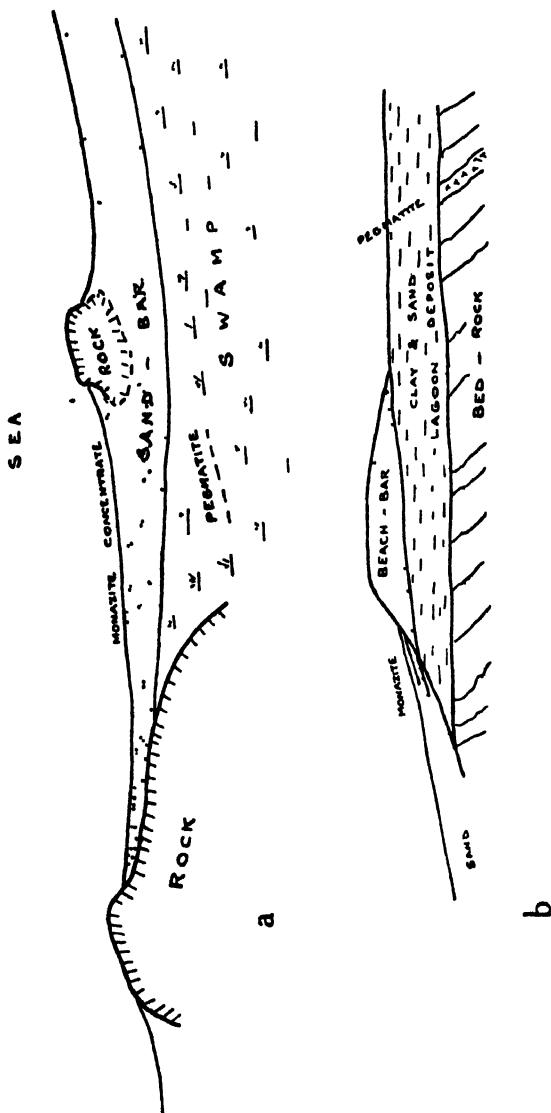
Fig 7   a, Diagram of Kaikawela Monazite beach deposit   b, Section across beach.

PLATE XI

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The hatching in the drawings is conventional. Hatching at right angles indicates pyroxenes; at an angle of 60°, hornblende; parallel lines indicate biotite. The same conventions are used in all drawings.

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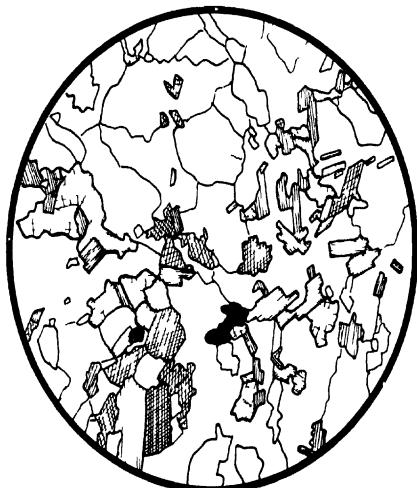
Fig. 1.—Garnet (stippled) and green augite (hatched) with subordinate plagioclase, and iron-ore which may be included in garnet or augite. (× 8.)

Fig. 2.—Garnet with inclusions and hornblende (cross-hatched) with plagioclase and rare augite. (× 8.)

Hb = hornblende; A = augite; P = plagioclase.

Fig. 3.—Garnet with large iron-ore inclusions, and hypersthene in orthoclase (Or) & plagioclase (Pl)—from basic charnockite. (× 8.)

Fig. 4.—Poikilitic intergrowth of garnet and hypersthene. The smaller hypersthene bodies included in the garnet are nearly all in parallel optical orientation with the large mass, as shown diagrammatically by the cleavage cracks. From a basic garnetiferous charnockite of eclogite type.

Hypersthene hatched; garnet stippled.

PLATE XV

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PLATE XVI.—LEPTYNITES.

Fig. 1.—Typical acid leptynite, consisting chiefly of granular quartz and ortho-clase and plagioclase with ribbons of quartz and rare biotite. Another part of the same slide shows small garnets.

Fig. 2.—Typical leptynite with very strongly developed structure. The long ribbons are quartz separated by bands of granular quartz-orthoclase with rare biotite.

Fig. 3 —Hornblende-garnet leptynite.

Fig. 4.—Biotite-garnet leptynite showing the characteristic corona of granular plagioclase which surrounds the garnet. The structure of the corona is too fine to be shown in the drawing. All × 8.

PLATE XVI

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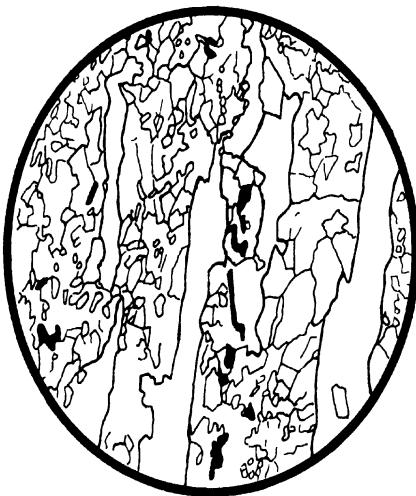
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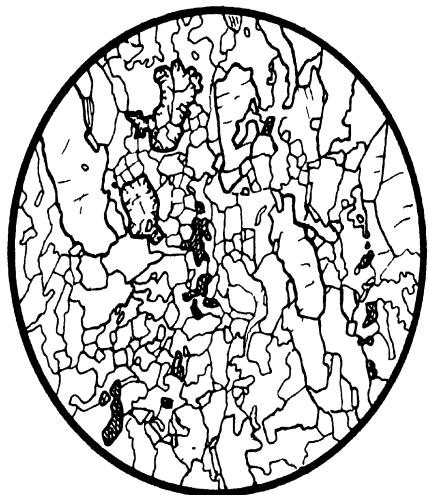
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PLATE XVII —MAGNETITE IN LEPTYNITE AND DOLERITE.

Fig. 1.—Garnet-magnetite intergrowth in crushed leptynite. The magnetite is surrounded by a border of kelyphitic felspar extending from its boundary to the adjoining garnets. The felspar contains a few sillimanite crystals (shown with dark borders) and a streak of small sillimanite prisms lies near one garnet, but separated from it by a clear zone of plagioclase (Pl). The upper edge of one garnet is ragged and bordered by myrmekite. Other iron-ore segregations are surrounded by clear felspar and encircled by biotite (Bi). (× 10.)

Fig. 2.—Iron-ore with kelyphitic felspathic border and myrmekitic quartz. (× 20.)

Fig. 8.—The same (× 20.)

Fig. 4.—Intergrowth of augite iron-ore and plagioclase in dolerite dyke. (× 20.)

PLATE XVII.

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MAGNETITE IN LEPTYNITE AND DOLERITE.

KHONDALITES AND ALLIED ROCKS

PLATE XX—LEPTYNITES.

Fig. 1. Leptynitic charnockite showing alteration of hypersthene to biotite.

Fig. 2. Crushed charnockite or leptynite, with biotite, garnet and relict hypersthene in fine-grained quartz-felspar mosaic and lenticles of quartz.

Fig. 3. More basic variety with hypersthene and biotite.

Fig. 4. Coarser grained variety.
All × 10.
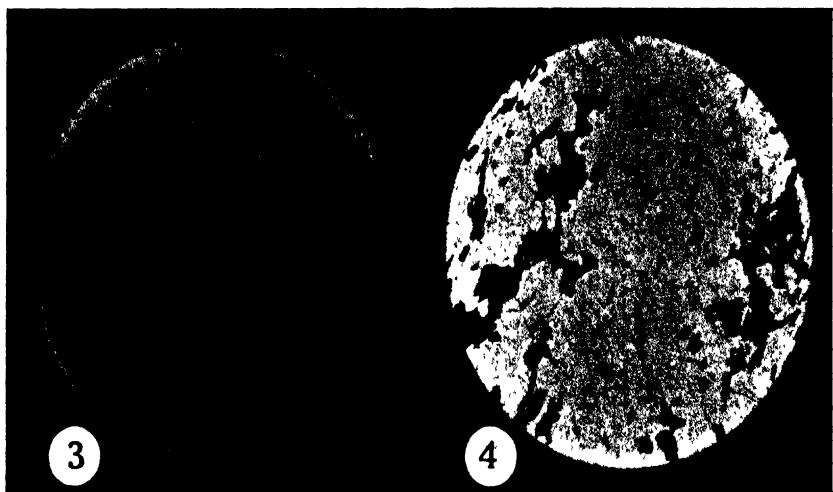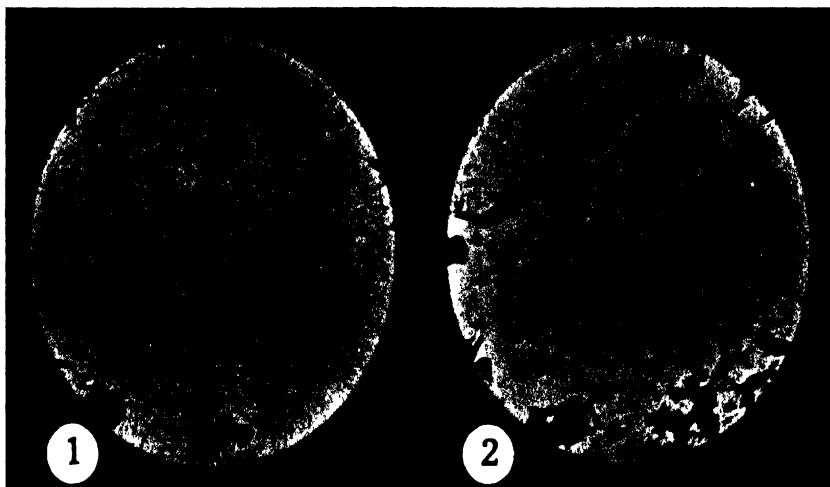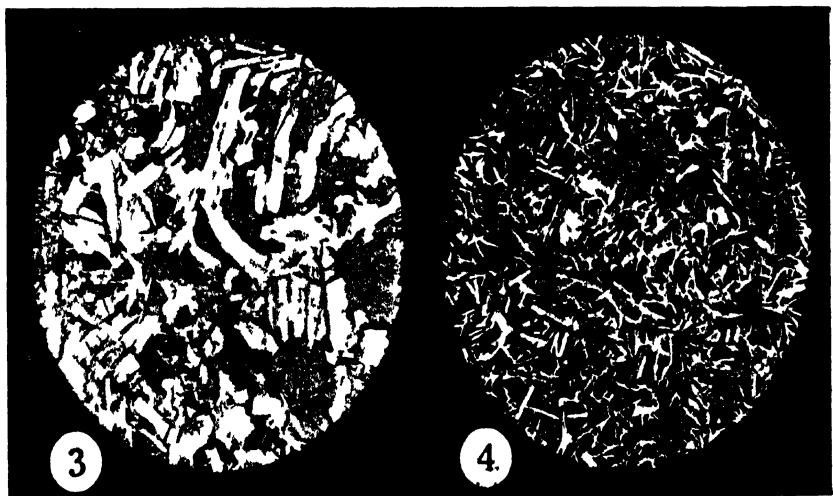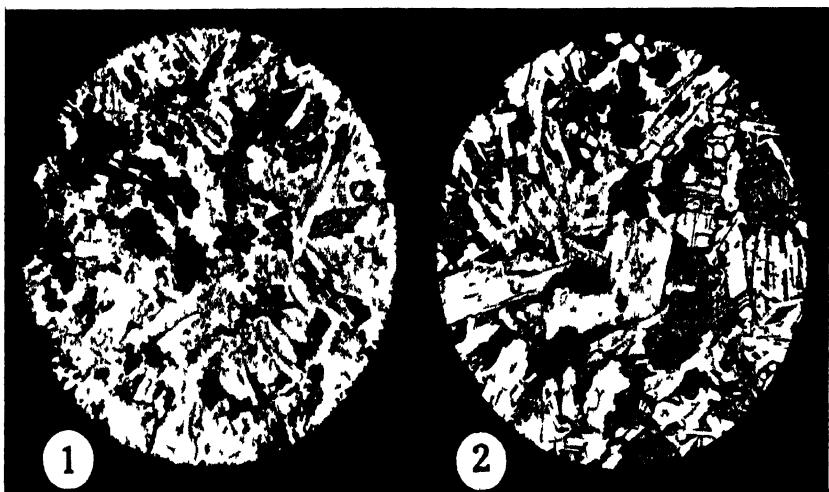
PLATE XXII.

Fig. 1. Graphic intergrowth of garnet and orthoclase. The dark inclusion in the large garnet is green augite. (× 10.)

Fig. 2. Green pyroxene and sphene with altered pyroxene and biotite in scapolite. The scapolite shows numerous acicular inclusions parallel to the vertical axis. From a vein traversing biotite-gneiss. (× 10.)
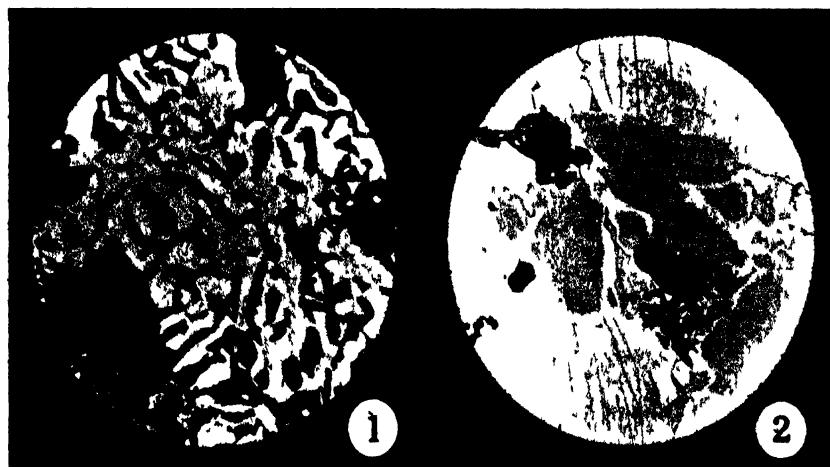
NOTE

The Porosity of Ceylon Rocks

BY

J. S. COATES, B.A. (Cantab.)

The idea is prevalent among engineers in Ceylon that the rocks of Ceylon are unduly pervious to moisture, and many cases of leaky walls have been explained as the result of this peculiarity. The experiments described in this article were begun with the object of testing this belief, and continued as a matter of interest. The determinations were made by Mr. P. T. Dirckze, Inspector of Mines, under my direction.

A similar series of determinations for Indian rocks was made by G. de P. Cotter and published in the Records, Geological Survey of India, LXVI, p. 348-355. The determinations were made by immersing a 5-inch cube in water for several days, without exhausting the air above the water. They probably therefore give too low a value for the porosity. Porosity determinations cannot be strictly comparable unless the method used is the same.

The method used in this instance was as follows:—A specimen of 20 to 50 gm. was repeatedly heated in an air-bath to 110° and then placed in an exhausted chamber, until the weight became constant. The specimen was then placed in a beaker under an exhausted bell-jar for an hour, to empty the pores of air, and water was then run in to cover it, without allowing the air pressure to rise above 20 mm. of mercury. When the specimen was completely covered air was admitted until the pressure became normal and it was allowed to remain under water for two days before being dried and weighed.

It was found impracticable to bring the dry specimen to an absolutely constant weight, on account of the rapid absorption of moisture from the air while it was being weighed. The coefficients, which were calculated from the formula: porosity $= \dfrac{\text{weight of water absorbed}}{\text{weight of specimen}}$ $\times$ 1,000 $\times$ specific gravity can be considered as accurate to the first decimal place.

The table gives the calculated porosity in cc of water absorbed per 1,000 cc. of rock, and the specific gravity of the rock.

For comparison the porosity coefficients of five small specimens of British rocks were determined by the same method. The values are given at the foot of the table.

The charnockitic rocks gave figures ranging from 2.07 to 5.18, the highest value being given by a rather crushed rock The crushed leptynite also gave a value well above the average. The biotite-gneisses which were of the fine-grained variety, and the pink Wanni gneisses also gave higher values than the charnockites.

The khondalitic specimens were quite fresh with no appearance of weathering. The low values they show in contrast with those examined by Cotter are very striking. Cotter's specimens gave coefficients varying from 10.6 to 79.3 and specific gravities from 2.362 to 2.494. The specimens were apparently ordinary building stones, which as pointed out by Fermor in a footnote to the paper, are almost always much weathered. It would appear that perfectly fresh specimens of khondalite are only slightly more porous than other crystalline rocks, and that the coarse garnet-sillimanite khondalite is well below the average.

The porosity coefficients of the Aberdeen and Stonehaven granites examined were 2.91 and 4.81 respectively The charnockites, which are very commonly used as building stones in Ceylon, show nearly the same range. The sheared leptynitic varieties are more commonly used on account of their fissility. They show rather higher values, but the difference is not great enough to allow them to be called porous. The pink granitoid gneisses come from sparsely populated areas, where stone buildings are rare.

In order to determine if possible the relation between the porosity coefficient of a rock and the rate of flow of water through it a hole was bored half way through an 8-inch cube of rock and a 16 feet water-pipe plugged into it. A narrow bore glass tube was fitted into the upper end of the pipe and it was filled with boiled water. The rate of fall of water-level in the pipe was too small to be observed. At the end of twelve months the water level had fallen 12 inches, corresponding to a loss of 0.25 cubic inches of water, part of which was undoubtedly due to evaporation The rock used for the experiment had a porosity coefficient of 8.78. It is therefore evident that rocks with a porosity coefficient not exceeding this figure, may for practical purposes be considered as impervious to water.

Description of Rock

CEYLON ROCKS

	Charnockites		*Porosity.*	*Sp. Gr.*
1.	Fine grained		3.14	2.800
2.	Medium grained, intermediate		2.17	2.767
3.	Do.	do.	3.34	2.695
4.	Do.	do.	2.67	2.839
5.	Do.	do.	5.18	2.919
6.	Do.	do.	· 3.84	2.767
7.	Do.	basic	4.34	3.148
8.	Do.	do.	2.07	3.168
9.	Do.	do.	3.07	3.112
10.	Do.	do.	3.70	2.736
11.	Leptynite		8.78	2.732
12.	Biotite-gneiss		7.79	2.630
13.	Do.		5.30	2.679
14.	Do.		3.99	2.738
15.	Pink granitoid gneiss (Tonigala type)		5.03	2.660
16.	Do.		7.43	2.633
17.	Do.		6.41	2.640
18.	Khondalite		3.82	2.642
19.	Do.		6.78	2.717
20.	Do.		6.95	2.640
21.	Do. (garnetiferous)		1.24	3.244
	Pink granulite		9.33	2.638
22.	Dolerite		2.62	2.974

BRITISH ROCKS

23.	Aberdeen granite		2.91	2.660
24.	Stonehaven granite		4.81	2.636
25.	Basalt, Mull.		5.20	3.044
26.	Diorite, Jersey		1.05	2.843

A New Species of Cestode, Dilepis lepidocolpos, from the Little Cormorant (Phalacrocorax niger)

BY

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(With Three Text Figures.)

The tapeworms forming the basis of this account were found in the small intestine of a Little Cormorant, *Phalacrocorax niger* (Vieill.), shot at Konwewa, N.C.P., Ceylon. There were two worms present and their scolices were deeply embedded in the wall of the gut, a fibrous cyst of about 6 mm. in diameter being formed round each scolex. The worms measure about 20 cm. in length and have a maximum breadth of 1.8 mm. The region immediately behind the scolex, chiefly that part which lay within the cyst, is segmented but constricted and neck-like : this narrow region measures 0.6 mm. in breadth and extends for 4.5 mm. There are about 450 proglottides, the number being difficult to determine in the anterior region of the strobila where there is much transverse creasing. Mature and gravid proglottides are only slightly broader than long but immature proglottides are very short relative to their breadth.

The scolex, 700 μ in breadth, is provided with four round suckers each 260 μ in diameter. The rostellum is 330 μ broad and armed with a double crown of twenty hooks, the larger measuring 105 μ and the smaller 84 μ. There is no neck, strobilization starting immediately posterior to the scolex.

The genital apertures are unilateral, situated on the left side of the body near the anterior limit of the proglottis. There are two excretory canals on either side, one lying directly over the other. The dorsal excretory canals are narrow, 15 μ in diameter, and their

comparatively thick walls are associated with glandular cells, while the ventral canals, 60 μ in diameter, are connected posteriorly by a transverse canal.
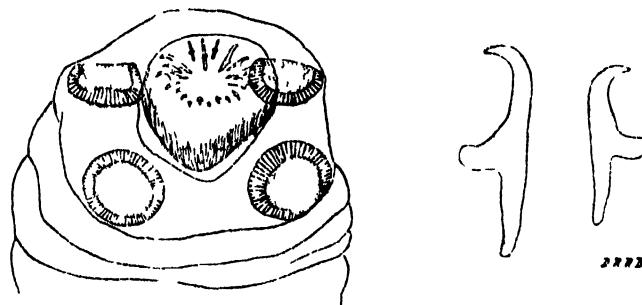
Fig. 1   *Dilepis lepidocolpos* sp. nov.   Scolex, × 50.   Hooks, × 260
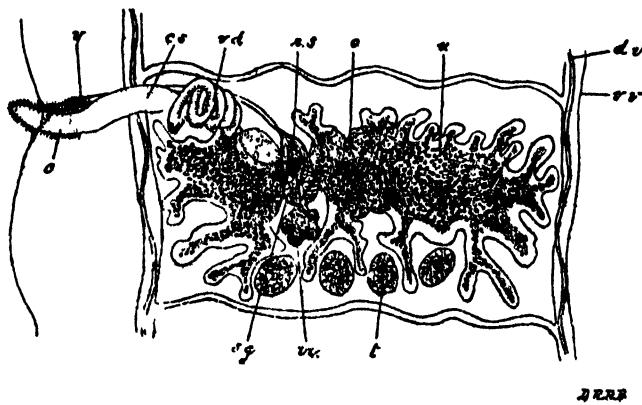
Fig. 2.   *Dilepis lepidocolpos* sp. nov.   Mature proglottis, × 48.   *c.*, cirrus; *c.s.*, cirrus sac.; *d.v.* dorsal excretory canal; *o.*, ovary; *r.s.*, receptaculum seminis; *s.g.*, shell gland; *t.*, testis.; *u.*, uterus; *v.*, vagina; *v.d.*, vas deferens; *vi.*, vitellaria; *v.v.*, ventral excretory canal.

Male genitalia. There are normally four testes which lie in a transverse row posteriorly behind the female genital glands. In some proglottides a fifth testis is present, while in others the number is reduced to three, and in one case to two only. The proportion of cases in which the normal number four is departed from is small: in 250 consecutive proglottides six exhibited five testes, ten had three, and one had only two. The cirri which are protruded in all mature and all the gravid proglottides in both tapeworms, are armed with slightly curved spines 8.5 μ long. In each proglottis a much coiled vas deferens opens into the cirrus sac in which an internal seminal vesicle is present. The length of the cirrus and the cirrus sac is about a quarter the breadth of the proglottis. The cirrus protrudes from a shallow genital atrium which lies close to the anterior limit of the proglottis.

Female genitalia. An unusual feature in this worm is the presence in one and the same proglottis of testes, ovary, and uterus containing ova. The ovary is bilobed, each lobe being formed from a number of blunt acini; the acini are few in the younger but more numerous in the older proglottides. The ovary is situated asymmetrically being slightly poral in position. The ducts from each lobe of the ovary unite to form the oviduct which leads posteriorly to receive a duct from the large receptaculum seminis which lies dorsal to the oviduct. The common duct bends antero-dorsally to enter the shell gland (75 μ in diameter) in which it receives the vitelline duct. The vitelline gland is slightly lobed and lies ventrally posterior to the ovary. The uterus leads from the shell gland to bifurcate forming a transverse lobate sac. In a mature proglottis the ovary measures 90 μ across, while the extent of the vitellaria is 60 μ. The vagina lies ventral to the cirrus sac, but opens into the genital atrium ventral and anterior to the base of the cirrus. In its distal portion the vagina is provided with spines, of about the same size as those arming the cirrus. The armed region of the vagina extends from the genital atrium to 225 μ from it, the wall of this region of the vagina is thicker than the remainder and is also surrounded with glandular cells. The genital ducts pass dorsally over the excretory canals.

As the uterus develops, its lobes extend between the testes, and only in posterior gravid proglottides where the testes are degenerating does it extend into the cortex.

The ova are numerous measuring 10.5 μ in diameter, while their nuclei measure 3.2 μ in diameter. Embryos are 28 μ in diameter and onchospheres 29.5—35 μ, each with six hooks 12.5 μ long.
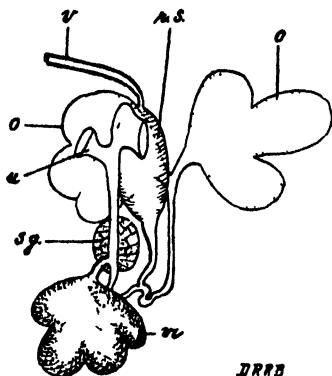
Fig. 3 *Dilepis lepidocolpos* sp nov. Arrangement of female genitalia, re constructed from serial sections Lettering as in Fig. 2

Muscular system   The cortex is separated from the medulla by a layer of circular muscles   Measured dorsoventrally the medulla is about one-third the thickness of the proglottis   External to the circular muscular layer lie the well-developed longitudinal muscles which are concentrated into about eighty bundles, forty dorsal and forty ventral.   Between this muscular layer and the cuticle are a few longitudinal muscles which form an indefinite second longitudinal layer

This tapeworm is believed to be an undescribed species and the name *Dilepis lepidocolpos* is proposed for it.

Discussion.

The genus *Dilepis* Weinland 1858, is defined by Fuhrmann (1932) as follows ' Dilepininae with rostrum armed with two crowns of hooks. Genital pores unilateral.   Genital ducts pass dorsal to the excretory canals.   Testes numerous, situate behind and on either side of the female genital glands.   Uterus sac-shaped, lobed.   Parasites of Birds, rarely of Mammals.   Type *Dilepis undula* (Schrank 1788) '   The new species fulfills the conditions of the definition of this genus with the exception of that pertaining to the number of testes.   But in a few species the number is reduced, as in *D. kempi* which has three testes and *D. delachauxi* which has four, so that the definition should be amended to read ' Testes usually numerous.'

So far only three species of *Dilepis* are known from the Pelecaniformes:—*D. kempi* Southwell 1921, *D. scolecina* (Rudolphi 1819) and *D. Delachauxi* (Fuhrmann 1909).

Dilepis kempi Southwell 1921.

Syn : *Hymenolepis kempi* (Mayhew) 1925.

Host : The Little Cormorant, *Phalacrocorax niger*—Southwell.

Locality : North Loktak Lake, Manipur, Assam.

Dilepis scolecina (Rudolphi 1819), Fuhrmann 1908.

Syn : *Taenia scolecina* Rudolphi 1819, Bremser 1824, Krabbe 1869

     Dilepis scolecina Joyeux et Baer 1928, 1930.

Host: *Pelecanus carbo* (L)—Rudolphi, Bremser; *Phalacrocorax africanus* (Gmelin)—Joyeux et Baer; *Phalacrocorax carbo* (L)—Lühe 1910. •

Locality : Niger Valley, between lakes Debo and Bemake, Africa.

Dilepis delachauxi (Fuhrmann 1909).

Syn : *Oligorchis delachauxi* Fuhrmann 1909.

     Dilepis delachauxi (Joyeux et Baer 1930).

Host: *Phalacrocorax africanus* (Gmelin)—Fuhrmann, Joyeux et Baer.

Localities: Egypt—Fuhrmann; Niger Valley (as in *D. scolecina*)—Joyeux et Baer.

The new species can be distinguished from *D. kempi* and *D. delachauxi* by the size of hooks alone, as can be seen in the following table :—

	Large.	*Small.*	
D. kempi	175 μ	135 μ	Southwell 1921
D. scolecina	93 μ	64 μ	Krabbe 1869
D. scolecina	103 μ	63 μ	Joyeux et Baer 1928
D. scolecina	100 μ	64 μ	Joyeux et Baer 1930
D. delachauxi	465 μ	282 μ	Joyeux et Baer 1930
D. lepidocolpos	105 μ	84 μ.	

The three independent measurements of the hooks of *D. scolecina* indicate something of the degree of variation in hook-size in this species, and form a basis of comparison more trustworthy than a single observation. While the larger hooks of *D. lepidocolpos* may be regarded as of the same size as the larger hooks of *D. scolecina*, the lengths of the smaller hooks are definitely of a different order. The original specimens

of *D. scolecina* described by Rudolphi (1819) were obtained from Bremser who figured them (1824, Plate 16, Fig. 15-18). The illustrations show a small worm, less than an inch long, with a large head, and with lateral processes which are apparently the protruded cirri. Rudolphi notes in his description of the worm ' Articuli anterioris, majorisque simul corporis partis, brevissimi, priores rugaeformes : marginibus satis aequalibus, lemniscis unilateralius brevibus truncatis, mox copiosis, mox potius sparsis, saepius ubique latentibus.' In this respect the two worms agree, but they differ in the presence of mature male and female reproductive glands in one and the same proglottis, of which point Rudolphi makes special note ' Vermis iste singularis spadici multorum florum instar anteriori parte masculus, posteriori femineus videtur, dum alias Taeniae articulos singulos androgynos exhibent.' A comparison of some of the diagnostic characters of both species is sufficient to indicate that we are dealing with two distinct species. The diameter of the scolex in *D. scolecina* is 500 μ while it is 700 μ in the new species; the rostellum and suckers are 300 μ and 260 μ in diameter respectively in the new species and 200μ and 170 μ in *D. scolecina*. The cirrus is protruded in both, but measures 190 μ × 80 μ in *scolecina* and 153 μ × 34 μ in *lepidocolpos*, while the external vaginal aperture is posterior to the cirrus in *scolecina* and antero-ventral to it in *lepidocolpos*. The muscular system shows a different development in the two species, in *scolecina* it is strongly developed and consists of a single layer of 200 bundles of fibres, while in *lepidocolpos* there is a strongly developed inner layer of about 80 bundles, a poorly developed outer layer, and a circular layer separating the cortex from the medulla. The testes are numerous in *scolecina* but normally only four in *lepidocolpos*, while the ovary in the latter species is asymmetrical in position being situated towards the poral side of the proglottis. This latter condition is seen also in *D. delachauxi* Fuhrmann (1909) (Page 29, Figs. 36-37).

One point of curious similarity between the two worms is the manner of fixation to the host, in which the scolex, having penetrated the submucosa to the muscles, lies in a sac which has formed round it. This condition was noted with regard to *scolecina* by Joyeux et Baer in 1928, in *Lateriporus mahadiaensis* by Joyeux in 1923, and in *Parorchites zederi* (Baird 1853) by Raillot et Henry (1912), F. Clausen (1915), and Fuhrmann (1920).

There are three points in particular which distinguish this worm from others of the same genus, and which severally or collectively warrant its inclusion in a new species. These are the asymmetrically placed

ovary, the presence of spines both on the cirrus and lining the vagina and the presence in gravid segments of both testes and ovary. In addition, the reduced and constant number of testes is a specific and diagnostic character.

Synopsis of diagnostic characters

Dilepis lepidocolpos, sp. nov.

Host: *Phalacrocorax niger* (Vieill.), the Little Cormorant.

Locality: Ceylon.

Size: 20 cm. long by 1.8 mm. broad, about 450 proglottides.

Scolex: 700 μ broad, with four suckers 260 μ in diameter. Rostellum 330 μ broad and armed with a double crown of 20 hooks; larger hooks 105 μ, smaller hooks 84 μ.

Genital Apertures: Unilateral, situated close to anterior limit of proglottis on left side.

Male genitalia: Cirrus 153 μ × 34 μ, protruded, and armed with recurved spines 8.5 μ long. Testes normally four, situate in a transverse row posterior to ovary and confined to the medulla.

Female genitalia: Vaginal aperture in genital atrium antero-ventral to cirrus. Vagina armed with spines 8.5 μ long.
Ovary slightly poral in position.

Genital ducts pass dorsal to excretory canals.

Excretory Canals: Narrow dorsal and wide ventral canal on each side, ventral canals connected posteriorly by a transverse canal.

Ova 10.5 μ ; *Embryos* 28 μ ; *Onchospheres* 29.5—35 μ , each six hooks 12.5 μ long.

The type specimen will be deposited in the British Museum (N.H.).

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Descriptions of some new Carabidae from Ceylon (Part III)

H. E. ANDREWES

My, two former papers in this series were published in this Journal (i) in Vol. XII, Part 46, 1923, pp. 223-251, and (ii) in Vol. XIII, Part I, 1924, pp. 129-141. Last year a further consignment of Carabidae was sent to me by Mr. G. M. Henry from the Colombo Museum, and among the species comprised in it were several new ones, of which nine are described here. The description of one further new species will also be found of which a single specimen was taken many years ago by the late George Lewis; this is now in the British Museum.

The type specimens of the new species are being returned to the Colombo Museum for the purposes of registration, figuring, and so on, but they will all ultimately be placed in the British Museum.

Coptolobus ater, sp. nov.

Length, 15.5 mm.

Black, dull: antennae and palpi piceous.

Head with the clypeal suture fine but quite visible, frontal impressions shallow, linear, disappearing gradually and just reaching vertex, mandibles with two distinct carinae on the upper suface, parallel near base, eyes small, genae inconspicuous, antennae with joint 2 barely longer than 3. *Prothorax* convex, a little wider than head, a third wider than long, sides with two setae near front angle and one behind; median line very fine but distinct, front transverse impression just traceable, surface smooth. *Elytra* convex, barely wider than prothorax, two-thirds longer than wide, border thickened and slightly angulate at shoulder, but not forming any tooth, base with a transverse row of minute irregular tubercles, extending to the

lateral channels, where they become regular; striae just visible close to base, but hardly traceable elsewhere, intervals quite flat, four conspicuous dorsal pores on the site of stria 3 at a fifth, three-fifths, four-fifths, and close to apex, surface smooth and dull, microscopically granulate and strigose, but showing only traces of a normal microsculpture. Underside smooth, ventral segments rather lightly transversely sulcate.

Mousakande, Gammaduwa, 1 ex.

Allied to *C. glabriculus* Chaud. (See Andrewes *Fauna of British India, Carabidae* i., 1929, p. 212), but dull instead of polished and shiny, the genae not protruding, the elytra longer and without any tooth at shoulder.

Psilus validus, sp. nov.

Length, 5 mm.

Black, shiny, buccal organs, antennae and legs ferruginous.

Head long, somewhat narrowed in front, facial sulci parallel and very deep in front, diverging towards eyes behind, labrum 5-setose, clypeus truncate, unbordered, wings extending forward on each side as flattened plates, rounded at apex (as in *Sparostes* but on a smaller scale), clypeal suture obsolete, vertex separated on each side from genae by a deep sulcus, which is externally bordered; eyes flat, embedded behind in the genae, which are shorter than eyes and curve round sharply to neck; neck with a narrow, punctate constriction much deeper at sides; antennae moniliform, not reaching base of prothorax, joint 3 almost as long as 2, surface smooth.   •

Prothorax convex, a half wider than head, as long as wide, widest just in front of hind angles, base evidently wider than apex. Sides straight in front, gradually dilated to hind angles, then sharply rounded to base, border entire, hind angles clearly dentate; median line and front transverse impression clearly cut though not very deep, the latter crenulate, just reaching margin at extremities, surface vaguely strigose.

Elytra convex, a fifth wider than prothorax, nearly three-fourths longer than wide, widest behind middle, shoulders rather square, clearly dentate, border not extending far inwards beyond shoulder; striae deep, very finely punctate, intervals convex, almost costate, 3 with four pores on the right elytron, three on the left. No appreciable microsculpture. Protibiae with well developed digitations.

of which the apical one is rather longer than the spur; mesotibiae with a short outer spine towards apex (as in many species of *Clivina*); all tarsi with joint 1 as long as the rest together.

Battaramulla (W. P.), 1 ex.

A full account of the genus will be found in my first volume on Carabidae in the *Fauna of British India* series, 1929, p. 386, and a key to all the then known species in *Ann. Mag. Nat. Hist.* (9) XX, 1927, p. 266. This species, which differs from all those hitherto described in having a spur on the mesotibiae, comes near *P.paradoxus* Putz., but the colour is black, the head is much larger, the labrum 5-setose, the prothorax with its sides straight in front, the elytral intervals almost costate.

Callistomimus pernix, sp. nov.

Length, 6 mm.   Width, 3.25 mm.

Black: head and prothorax dark red above and beneath, the former with a piceous area on middle of vertex and front; buccal organs and joint 1 of antennae ferruginous; legs flavous, elytra with some small yellowish white spots, viz., (i) an oblique stripe, running backwards from shoulder to stria 5, subinterrupted on interval 6, (ii) an apical spot on intervals 6-8 with an additional very small spot just in front on interval 4, (iii) a very small common spot at extreme apex. Surface pubescent.

Head convex, closely rugose-punctate, eyes convex, rather small. *Prothorax* convex, cordate, a fourth wider than head, a fifth wider than long, base hardly wider than apex, sides strongly rounded in front, very gently sinuate behind, hind angles projecting on each side a little before the apparent base as a slightly acute and very sharp tooth; median line slight, basal foveae rounded and moderately deep, closely punctate.

Elytra subovate, convex, shoulders rounded but quite evident, about three-fifths wider than prothorax, two-fifths longer than wide; striae finely punctate and moderately impressed, intervals 3 and 5 a little wider than the others, surface closely punctate, much more finely than that of the head and prothorax. Microsculpture of the elytra formed by a kind of isodiametric granulation, which, owing to the coarser puncturation, is hardly visible on the head and prothorax. Sterna finely punctate, venter more finely and sparsely.

Vavuniya (N. P.), 1 ex.,

Near *C.jucundus* Andr., but the head and prothorax are red instead of aeneous and the surface generally is more finely punctate. The hind angles of the prothorax present a distinguishing feature; in *pernix* they are small, rectangular, and do not project backwards, whereas in *jucundus* they are large, acute, and project for some distance backward, each one separated from the median part of the base by an acute-angled notch.

Holcocoleus melanopus, sp. nov.

Length, 9.5 mm.   Width, 4.25 mm.

Black, underside and legs dark ferruginous; sides and base of pro-thorax, apex of elytra, and joints 4 to 11 of antennae piceous; joints 1 to 3 of antennae and buccal organs flavous. Upper surface glabrous, and microscopically punctate.

Head convex, smooth, clypeal suture with an elongate pore at each end, between which and eye there are on each side some vague longitudinal rugae, a row of shallow punctures running across vertex, eyes moderately prominent, antennae slender, not quite reaching base of prothorax. *Prothorax* convex, forming with elytra an almost regular oval, twice as wide as head, three-fourths wider than long, sides with a narrow reflexed border, without lateral setae, explanate, narrowly in front, widely behind; median line rather fine, basal foveae represented by a small but deep puncture on each side, at some distance from base, and nearer middle than margin, surface a little uneven. *Elytra* convex, barely wider than prothorax, a little more than a half longer than wide, shoulders not dentate, basal border extending inwards to stria 3; striae very deep and finely punctate, 8 joining the marginal' channel a little before middle, a slight scutellary striole present, intervals very convex, 8 only half as wide as the rest, costate behind, 9 widening out behind and covered with minute irregular tubercles, 3 with two pores, one behind middle and another towards apex. Microsculpture of the elytra formed by meshes on average three times as wide as long; on the head and prothorax the meshes are isodiametric. Prosternal pro-cess bordered, metepisterna a little wider than long; last ventral segment (♂) with a single marginal seta on each side.

Elephant Pass, 1 ex. ♂

Very near *H.latus* Laf., the only other described species, but other-wise coloured, the sides of the prothorax more evidently explanate, the elytral striae much deeper, and the intervals more convex, the dilated ♂ protarsal joints longer and narrower.

Xenodus mediocris, sp. nov.

Length, 8-8.5 mm.

Black, shiny, buccal organs and antennae ferruginous, tarsi piceous.

Head rather wide, convex, smooth, eyes small, prominent, antennae slender, extending rather beyond base of elytra. *Prothorax* quadrate, convex, a third wider than head, not quite a third wider than long, base truncate, very slightly wider than apex, sides rounded, border reflexed, the seta placed at two-fifths from apex, hind angles obtuse and rounded, though quite evident, not reflexed; median line and transverse impressions rather slight, basal foveae shallow, surface smooth, the whole basal area punctate, closely at sides, sparsely at middle, the puncturation extending forward along the lateral channels.

Elytra convex, with parallel sides, a little wider only than prothorax nearly three-fourths longer than wide, striae deep, finely punctate, intervals smooth and convex, no evident dorsal pores, intervals 8 and 9 finely punctate, and the whole apical area both finely punctate and setulose. Microsculpture of the elytra distinct, formed by very wide meshes; hardly any is visible on either the head or prothorax. Sterna more or less punctate, venter very finely and sparsely punctate, slightly setulose at apex.

Ceylon: Battaramulla, Bintenne, Kotte. India: Nagpur (*E. A. D'Abreu*).

Differing from *X.d'abreui* Andr., the only other described Indian species, not only in its very much smaller size, but also in having the apex of the elytra pubescent. The general form of the insect is similar. The Nagpur ex. differs from the Ceylon specimens in having the tibiae ferruginous.

Dicranoncus ravus, sp. nov.

Length, 6.5-7 mm.

Ferruginous, lighter beneath: prothorax with a vague brownish cloud on each side of disk, elytra, except intervals 1 and 9, the marginal channel, and epipleura, very dark brown.

Head small, convex, smooth, strongly contracted behind, frontal foveae obsolete, eyes moderately prominent, antennae very slender, not reaching very far beyond base of elytra.

Prothorax slightly convex, rather more than a half wider than head, a fifth wider than long, base evidently wider than apex, all the angles rounded, the front less than the hind ones, sides unbordered, bisetose, slightly reflexed behind, and fairly widely explanate; median line and transverse impressions all rather shallow, basal foveae rounded, moderately deep, surface smooth. *Elytra* convex, elongate-oval, two-fifths

wider than prothorax, rather less than three-fourths longer than wide, basal border entire, bi-emarginate, forming a sharp angle at shoulder on each side, a slight emargination on each side behind, and a small spine at apex; striae fine but moderately impressed, minutely crenulate, intervals slightly convex, 3 with three small dorsal pores, surface smooth, a rounded depression on each side covering intervals 3-6 at two-fifths from apex. Microsculpture of the elytra formed by meshes about twice as wide as long; on the prothorax the meshes are strongly transverse, and on the head isodiametric, in both cases very faint. Last ventral segment ♂ with one marginal seta, ♀ with two setae on each side. Tarsal joints bisulcate, joint 4 only slightly emarginate, joint 5 setulose beneath.

Ceylon: Mousakande, Gammaduwa. India: Nilgiri Hills (*H L. Andrewes*).

Very near *D.queenslandicus* Sloane, but the elytra are brown instead of piceous-black, interval 8 is dark throughout, and all the intervals are much less convex. *D.cinctipennis* Chaud. is larger, with metallic green elytra.

Genus Risophilus.

In the *Indian Forest Records* (XVIII, part v, 1933, p. 12) I gave a key to all the species of this genus found in the Indian region. Among the Ceylon species comprised in this table there is only one (*repandens*) in which the shoulders of the elytra are quite rounded away. Below will be found the descriptions of three new species which are similar in this respect, and which may be distinguished as follows :—

1 (4) Elytra rather flat, with two dorsal pores on interval 3, none on 5 or 7.

2 (3) Elytra widely explanate at sides behind, intervals only moderately convex, colour of disk light brown, sides-piceous. Length, 3.75 mm.

repandens Walk.

3 (2) Elytra not explanate at sides behind, odd intervals strongly convex, colour piceous throughout. Length, 4 mm.

oryctus, sp. nov.

4 (1) Elytra convex, with dorsal pores on intervals 3, 5 and 7. Length, about 4.25 mm.

5 (6) Elytra with moderately impressed striae and convex intervals, 3 (usually) with five, 5 with four, and 7 with three pores, colour piceous with the apex yellowish white

trigonus, sp. nov.

6 (5) Elytra with faint striae and flat intervals, 3 with two pores, 5 with one pore, and 7 with four pores, colour uniform piceous

levipennis, sp. nov.

Risophilus oryctus, sp. nov.

Length, 4 mm.

Piceous above: underside, buccal organs, antennae and legs, ferruginous.

Head smooth, very convex behind, frontal foveae small and rounded, a slight fovea on each side close to eye, eyes flat, antennae slender, nearly reaching middle of elytra. *Prothorax* as wide as head and as wide as long, widest slightly before middle, base evidently wider than apex, sides bisetose, very gently rounded in front and faintly sinuate behind, hind angles a little obtuse, fairly sharp, and slightly reflexed; median line and the two transverse impressions all rather shallow, basal foveae fairly deep, continued some little way forward, surface generally smooth, slightly rugose in the foveae. *Elytra* sub-triangular, rather flat, more than twice as wide as prothorax, two-fifths longer than wide, strongly dilated behind and widest at apical third, shoulders completely cut away, apex truncate on each side, border extending inwards at base to a point opposite stria 4 and gently rounded behind to the apical truncature; striae fairly deep, impunctate, intervals rather irregular, the even ones moderately, the odd ones more strongly convex, but all are equally convex close to base, 3 with two very large pores occupying more—the hind one considerably more—than the width of the interval, placed at about a fourth and three-fourths. Microsculpture isodiametric but rather indistinct throughout. Venter setulose, apical segment (♀) with two marginal setae on each side; claws distinctly pectinate.

Bogawantalawa (*G. Lewis*), 1 ex. ♀

The solitary example of this species, now in the British Museum, was left undescribed by H. W. Bates, when in 1886 (*Ann. Mag. Nat. Hist.* (5). XVII), he was dealing with the Lewis collection.

The species comes near *repandens* Walk.

Risophilus trigonus, sp. nov.

Length, 4-4.5 mm.

Ferruginous, upper surface piceous, elytra with the marginal channels and sometimes interval 9 dark ferruginous, apex for about a sixth of the total length yellowish white; underside dark ferruginous to piceous.

Head convex, smooth, neck slightly constricted, frontal foveae small, rounded, and deep; eyes moderately prominent, antennae stout, not extending far beyond base of elytra. *Prothorax* very slightly wider than head, and a little wider than long, equally wide at base and at a point about a fourth from apex, base a little wider than apex, sides bisetose, gently rounded in front and gently sinuate behind, hind angles right, moderately sharp, and projecting a little laterally; median line moderately impressed, hind transverse impression and basal foveae both deep, the latter with a small raised area in each not far from the angles, surface vaguely transversely striate. *Elytra* convex, sub-triangular, rather more than twice as wide as prothorax and a little more than a half longer than wide, strongly dilated behind and widest at about apical third, shoulders completely rounded away, apex trun-cate on each side, border extending inwards at base to a point opposite stria 5, and gently rounded behind to the apical truncature; striae moderately impressed, impunctate, intervals somewhat convex, but rather irregular, 3 with about five large pores, 5 with four, and 7 with three, but the number in each is variable. The meshes of the micro-sculpture are isodiametric on the head and elytra, a little wider than long on the prothorax. Venter setulose, apical segment with 1 marginal seta on each side in the ♂, 2 setae in the ♀; claws very distinctly pectinate.

Kandapola (1 ex. on Goatfell); Hakgalla.

In my key to the Indian species this one would come near *catenatus* Bates and *intermedius* Bates.

Risophilus levipennis, sp nov.

Length, 4.25 mm.

Similar in form and colour to *R.trigonus*, but there is no apical pale band across the elytra, and the head and prothorax are less shiny.

Head similar, but with a short oblique impression on each side opposite the eye, the two impressions converging a little behind. *Prothorax* with the hind angles right but hardly reflexed, and not pro-jecting laterally, the median line similar, but the other impressions much shallower. *Elytra* shorter, twice as wide as prothorax, about a third wider than long, but otherwise similar in shape; striae very lightly impressed, almost obliterated on disk, but visible throughout, intervals flat, 3 with two pores, one towards base, the other not far from apex, 5 with a single pore close to base, 7 with four pores, surface a little

uneven especially near apex. Microsculpture similar but much more distinct, especially on the head and prothorax. Apical ventral segment (♀) with two marginal setae on each side.

Kandapola, 1 ex. ♀.

Lebia leucaspis, sp. nov.

Length, 7 mm. Width, 3.3 mm.

Ferruginous: prothorax with a slight brown spot on each side of disk, elytra yellowish white, with black markings, which consist of (i) a spot round the scutellum, covering the first four intervals on each side at base and very soon contracting suddenly to the first two intervals, the whole spot reaching basal fourth, (ii) an elongate spot on each side, covering the marginal channel and intervals 8-9, and extending from shoulder to apical third, throwing out an arm at about middle to stria 4, (iii) a slight median crescent at apical fifth, reaching stria 3 on each side. The apical border of the elytra is brown.

Head with rather slight frontal foveae, eyes large and hemispherical, surface uneven, and somewhat vaguely striate-punctate. *Prothorax* slightly convex, not much wider than head, a half wider than long, base moderately produced at middle, with a very obtuse angle on each side, front angles rounded away, sides bisetose, widely explanate, reflexed, rounded in front, nearly straight behind, hind angles slightly obtuse but moderately sharp; median line and hind transverse impression at middle both fairly deep, surface finely rugose-punctate. *Elytra* moderately convex, very nearly twice as wide as prothorax, a third longer than wide, shoulders square, rather strongly dilated behind and widest at about apical fourth, apical truncature emarginate on each side, the outer angles rounded; striae very deep, finely and vaguely crenulate, intervals strongly convex, 3 with two pores, at about a fourth and three-fourths respectively, surface impunctate Microsculpture isodiametric, though some of the meshes on the elytra are a little wider than long; on the head and prothorax the rough surface renders the meshes indistinct. Venter sparsely pubescent, apical segment more densely and with two marginal setae on each side (♀); tarsal joint 4 bilobed; claws pectinate.

Battaramulla, 1 ex. ♀.

I know of no Asiatic species with even an approximately similar pattern on the elytra.

Two Xiphiiform Fishes from Ceylon

BY

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(With Two Plates and Two Text Figures.)

In a preliminary account (1933) of the Xiphiiform fishes common in Ceylon waters, reference was made to the young of the sail fish *Istiophorus gladius* and also to the occurrence of the sword fish *Xiphias* off Ceylon. The present article gives in some detail, accounts of (1) a young *Istiophorus gladius* (2) the rostrum of a *Xiphias*.

Young Istiophorus gladius   Plate XXIII

(1) Although some post-natal growth stages of several Istiophoridae or sail fishes are already known, a young specimen recently taken in Ceylon waters discloses several features of interest.

Günther (1880) studied the young of an *Istiophorus* sp. and found that individuals 9 mm. long possessed beak-like, dentigerous jaws of equal length. The interorbital space was spinose and there was a strong preopercular spine and another at the angle of the parietal. The dorsal and anal fins were not differentiated into lobes. In specimens 14 mm. long the interorbit was no longer spinose, the dorsal fin had increased in depth and the ventrals were filamentous. In the 60 mm. stage, the upper jaw was longer than the lower, the teeth were absent, the parietal spine was much reduced and the anterior part of the dorsal fin was considerably deeper than the posterior. Cuvier and Valenciennes (1831) described and figured a young *Istiophorus* they named *Histiophorus pulchellus*. The specimen was collected by M. Raynaud when returning to France from the Cape in January, 1829. The animal as recorded, was 4 inches (102 mm.) long, possessed teeth on its jaws, a smooth preopercular spine and ventral fins with two rays. Their figure depicts a light coloured dorsal fin irregularly blotched and streaked with black, and differentiated into a deep anterior and

low posterior lobe. The fish is shown devoid of spinose scales and as the young of *Xiphias* with such scales is figured in the same volume, their absence in *Istiophorus* can scarcely be due to an oversight.

The young specimen [1] here dealt with was attracted by lamp light to a fishing canoe anchored in 24 fathoms off Egoda Uyana (Western Province) on April 5, 1934, at 7 P.M., and was taken in a dip net.

Description of the specimen. The fresh dead specimen was received for examination at 10 A.M. on April 6, 1934. Its stomach, which contained part of the vertebral column of a small fish, protruded from a wound to the abdomen. The dorsal fin was intact but so desiccated, that even after the specimen had remained in water for an hour, the tips of the median rays were inseparable without injury to the membrane. Jaws elongate, dentigerous; rostrum longer than man-dible, its component bones not fused, preorbital bone distinct; nostril close to the eye. Single toothed scales covered the body and much of the head (Fig. 2). Dorsal fin differentiated into a large, deep, anterior lobe confluent with a low posterior one. First divided ray of the ventral filamentous and much longer than either the ventral spine or second ray; its filamentous tips connected by membrane.

Measurements. Total length with rostrum and caudal fin 127 mm.; rostrum 46 mm.; eye 6 mm.; postorbital length of head 10 mm.; lower jaw (to end of gape) 20 mm.; depth of head 9 mm.; length of pectoral fin 10 mm.; greatest depth of dorsal 33 mm.; length of ventral 26 mm.; length of caudal fin 14 mm.

Colours. Dorsally bluish-grey, cheeks and sides of body silvery, crossed by about eight indistinct bluish-grey bands slightly wider than the interspaces. Rostrum dark. Anterior elevated part of dorsal fin dull blue with five elliptical spots, each at least twice as large as orbit. Free tips of dorsal rays white. Posterior part of dorsal, ventrals and anal white. Caudal white, each lobe tipped with black.
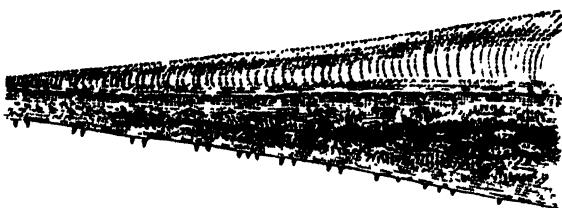
P. Deraniyagala del.

Fig. 1. Rostrum anterior to preorbital bone × 10

[1] This specimen will be deposited in the British Museum.

· *Teeth.* Well developed, acicular, with four terminal teeth in a horizontal plane on rostrum. Maxillary teeth uniserial anteriorly, in small oval patches posteriorly, and upon alveolar surface. Teeth of lower jaw in two ridges, wider apart on the inner ridge than on the outer. Tongue free with granular teeth.

P. Deraniyagala del.

Fig. 2. A lateral scale from mid body × 25

Scales; circular with four or five subconcentric rings around a central spine. None on interorbit or jaws. Twenty-six above and below lateral line, above origin of anal fin.

Fins. D. 52, P. 20, A. 20, C. 18. Dorsal fin differentiated into an anteriorly elevated lobe and posteriorly depressed one. Ventral with a short spine and a long and a short divided ray. A sheath for base of dorsal and a feeble one at base of anal. Many of the so-called spines of the anterior dorsal lobe possess branched terminations.

Body. Nostrils much closer to eye than in adult. Preorbital bone distinct, elongate, triangular and directed anteriorly along rostrum to above middle of length of lower jaw. Maxillary process reaches posterior edge of orbit. Angle of preopercle with a strong spine, serrate along its upper edge. Opercle with four spines at its upper angle, the superior larger than the inferior. Body neither more compressed nor rounded proportionately than in the adult.

The fin formula suggests that the specimen was the young of *Istiophorus gladius* Broussonet, and the pigmentation supports this view, for I have already stated (1933) that the spots on the dorsal and the light cross bands on the body tend to increase in numbers and intensity with age.

The early disappearance of dentition suggests that the species studied by Günther is probably distinct from that figured by Cuvier and Valenciennes. The Ceylon specimen differs from both in the following respects. (*a*) In possessing a well developed covering of spinose scales [1]

[1] There are numerous scales upon the rostrum and pectoral fins of the adult. Each scale is ring shaped with a fringe of spicules along the inner rim. Such a scale might result from a loss of the spine from the infantile scale.

which persist at least until the dorsal fin has more or less completed differentiation. (b) The teeth and preopercular spine are comparatively more persistent, and the general pigmentation of the fish is different.

It will be noticed that the genus *Istiophorus* possesses in common with *Xiphias*, the infantile character of spinose scales, which is probably a primitive feature. It is remarkable that *Xiphias*, which is considered the most highly specialized member of the giant mackerel-like fishes should retain a complete, spinose lepidosis (Jordan, Fig. 211) which is at times vestigial and probably even absent in such an unspecialized genus as *Istiophorus*. It is also noteworthy that *Istiophorus*, although more advanced than the Xiphiidae in this feature, is more closely allied to the primitive Palaeorhynchidae than any other living member of either the Istiophoridae or Xiphiidae.

The Palaeorhynchidae flourished from Eocene to Oligocene times and possessed a continuous dorsal and a ventral consisting of several elongate rays. Both features exist in *Istiophorus* in which the lobes of the dorsal fins are connected by at least a row of vestiges, whereas in the other genera they are separate.

The filamentous first ray of the young Ceylon specimen also discloses the composition of the spike-like ventral fin of the adult, and the fins suggest that the genus originated from an ancestor with a continuous dorsal and many rayed ventrals, as displayed by the fossil family.

Rostrum of **Xiphias**   Plate XXIV

The genus *Xiphias* Linné was unknown from the Indian Ocean when F. Day wrote his *Fishes of India* in 1878. Ten years later A. Haly, then Director of the Colombo Museum, recorded in his Administration Report that he had obtained ' the sword of a *Xiphias* which was caught at Hikkaduwa in January '. As he left no description or figures of this rostrum many doubted the accuracy of his identification, but Sinhalese fishermen along the south coast are familiar with a large *Makaira*-like fish with a depressed, pointed, blade-like rostrum and inquiry revealed the following information.

The fish is known to them as the ' kadu kopera ' or ' kiyath kopera ' derived from the shape of its rostrum for ' kaduwa ' signifies ' sword ' and ' kiyatha ' ' saw '. It is comparatively rare, the number captured annually being seldom more than two or three, although *Istiophorus* and *Makaira* number several hundreds. It is as large as the largest *Makaira*, with a proportionately longer rostrum. The first dorsal fin consists of a single lobe. The pectorals are longer than the first dorsal and while some fishermen affirmed that short

spike-like ventrals were present, others denied this. Subsequently in order to prove their statements they presented me with a rostrum which showed the features they had described. The shape and relative proportions of its component bones, when compared with those in the rostra of *Makaira indica* (Cuv. et Val.) and *Istiophorus gladius* (Broussonet) respectively, show that this rostrum undoubtedly belongs to a *Xiphias* for its bones agree in general arrangement with the figure of Cuvier and Valenciennes. Plate XXIV shows the three rostra in dorsal and lateral view respectively. In each instance the rostrum of *Xiphias* is in the middle with the rostrum of *Makaira*, above, and that of *Istiophorus* below. In dorsal view (Plate XXIV, fig. 2) the greater width of the depressed blade-like rostrum of *Xiphias* and the relatively larger dermethmoid bone are noticeable. The two splint-like bones, which extend anteriorly from either side of this bone, regarded as nasals by some (Tate Regan 1909), as premaxillaries by others (Gregory 1933), extend backwards as thin splints. In *Xiphias* these are much narrower than the dermethmoid, whereas in the other two fishes they are relatively wider.

In lateral view (Plate XXIV, fig. 5) the lower surfaces of the other two rostra face the rostrum of *Xiphias*. The latter, although exceeding the former in length, is so depressed that its depth is much less. It is also edentulous, whereas the other two rostra possess numerous fine teeth which in this plate are most evident along the lower edge of the rostrum of *Makaira* as a dark band (Plate XXIV, fig. 4). These characters prove that the ' sword ' undoubtedly belongs to a *Xiphias* and the question to be decided is its specific identity.

Fishes of the genus *Xiphias* are known from the Pacific Ocean and according to some workers differ from the Atlantic species *Xiphias gladius* Linné.

In 1905 Jordan and Evermann examined a Hawaiian specimen and found it inseparable from *X. gladius*. In 1926 after examining photographs of other Pacific specimens taken off South California, Santa Catalina Island, Hawaii, and New Zealand they still maintained this view although admitting ' a slight difference in the length of the sword and the pectoral fin '. In 1926 Phillips examined a figure of an eleven-foot specimen drawn by a Mr. Clarke, as well as a mounted adult in the Dominion Museum, New Zealand and concluded that the fish found in those waters was *X. gladius*. In 1932 Phillips again examined this material and designated the mounted specimen as the type of a new species *Xiphias estara*. He considered that in the new species, the eye was relatively larger and placed further forward than

in *gladius* and that the tip of the lower jaw was only slightly in advance of the eye, while the angle of gape was far behind the orbit. He stated that the reverse obtains in the jaw tip and angle of gape in *X. gladius*.

If both the mounted specimen and Clarke's sketch agree in these features it is evident that this New Zealand fish differs from the photograph of a Santa Catalina specimen reproduced by Jordan and Evermann (1926, pl. 20) and it is necessary to recognize more than a single species of *Xiphias*. None of these shows much difference between the proportionate lengths of the dorsal and pectoral. The contrary is affirmed by Sinhalese fishermen and it is possible that the Indian Ocean form is new.

Examination of its rostral bones and comparison with figures of the Atlantic form by Cuvier and Valenciennes (1831) and Tate Regan (1909) also show a possible difference in the relationship of the dermethmoid to the frontal bones. In Atlantic specimens the latter are in contact with the former for about one half their externally visible length; in the Ceylon specimen only the posterior fifth of the dermethmoid bone is thus enclosed by the frontals. As however its posterior extremity is wanting this estimate must be viewed with caution.

The dried rostrum cut off near the posterior extremity of the dermethmoid bone was presented to me at Gandara in the Southern Province on May 30, 1934. Its colour was a dark, slaty brown dorsally, yellowish ventrally. Viewed dorsally the rostrum (Plate XXIV, fig. 2) curved gently to the left but in side view (Plate XXIV, fig. 5) it was straight. There were no teeth but the margins and ventral aspect near the point were rugose. Its dimensions were as follows:—Total length 800 mm., width opposite posterior end of dermethmoid bone 65 mm., depth opposite anterior end of dermethmoid bone 20 mm., length of dermethmoid bone inclusive of its anterior prolongation which is exposed by drying 180 mm. This specimen is deposited in the British Museum.

The records of Indo-Pacific *Xiphias* spp. are as follows:—(a) 1883. Haly thought that the rostrum he obtained from Hikkaduwa in Ceylon might belong to *Xiphias gladius* Linné.

(b) 1905. Jordan and Evermann stated that a specimen they saw at Honolulu was *Xiphias gladius*.

(c) 1923. Nichols thought the tail end of a young Xiphiform fish, taken from the gullet of a red-tailed tropic bird captured off Rapa Island in the Austral Archipelago, belonged to some unknown form

and named it *Phaëthonichthys tuberculatus*. Subsequently the error was detected by Jordon and Evermann (1926, p. 71). It is questionable whether the sword-fish of the Pacific should be named *Xiphias tuberculatus* (Nichols), for it is not unlikely that the tail fragment, belonged to a young *Makaira*. It is also possible that there are several species of *Xiphias* in the Indo-Pacific.

(d) 1926. Jordan and Evermann continued in their belief that the Pacific had only *Xiphias gladius* and published a photograph of a specimen taken off Santa-Catalina Island.

(e) 1926. Phillips examined the sketch of a New Zealand sword fish executed by a Mr. Clarke. He also examined a mounted adult and concluded that the New Zealand fish was *Xiphias gladius*.

(f) 1930. McCulloch listed the Australian species of *Xiphias* as conspecific with *Xiphias rondeleti* described by Leach in 1818 from the Firth of Forth.

(g) 1932. Phillips again examined Clarke's sketch and the mounted adult and decided that the New Zealand *Xiphias* was new and named it *Xiphias estara*.

(h) 1935. The present author has examined the rostrum of a Ceylon *Xiphias* and, in view of the description of the fish given him by fishermen and some possible differences in the bones of the rostrum, tentatively suggests that the Indian Ocean form is a new species.

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P. E. P. DERANIYAGALA

EXPLANATION OF PLATES

PLATE XXIII.

Young of *Istiophorus gladius* × 1

PLATE XXIV.

The rostra of *Istiophorus gladius*, *Xiphias* sp. and *Makaira indica*. Viewed dorsally and laterally × ½ (Photographs)

Dorsal view.

Fig. 1.—Makaira indica
Fig. 2.—Xiphias sp.
Fig. 3.—Istiophorus gladius

Left lateral view.

Fig. 4.—Makaira indica
Fig. 5.—Xiphias sp.
Fig. 6.—Istiophorus gladius
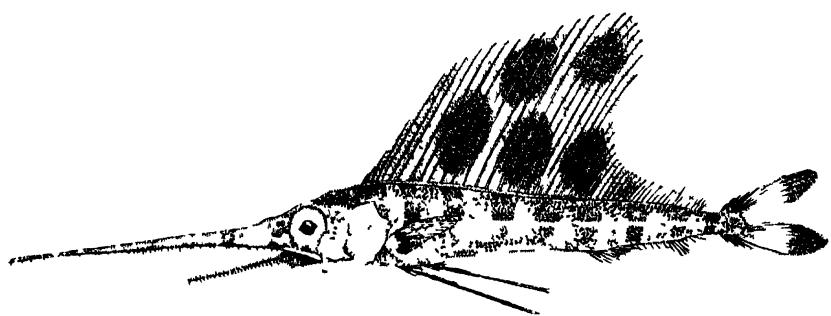
PLATE XXIII.

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Young *Istiophorus gladius* × 1

PLATE XXIV.
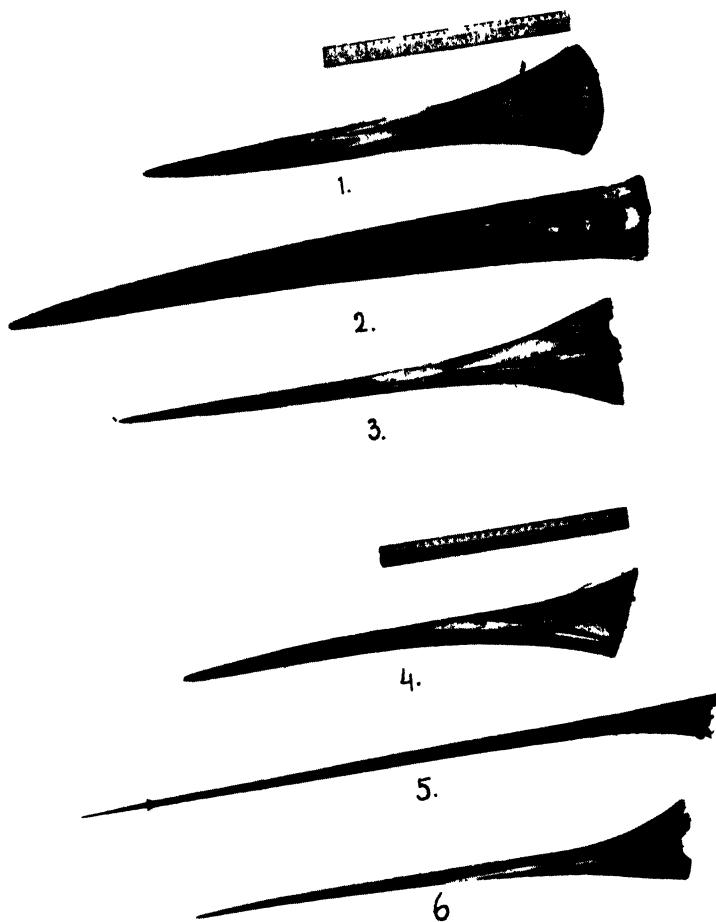
Rostra of Xiphiform fishes × ⅛

Two New Fishes from Ceylon

BY

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(With Three Text Figures.)

Genus **Vaimosa** Jordan et Seale

Bull, U. S. Bureau Fisheries, XXV, 1905. (*V. fontinalis*)

Body subcylindrical rather compressed posteriorly. Head bluntly rounded and with prominent eyes; cheeks and snout naked; sense pits developed. Nostrils apart, lower ones tubate and just above upper lip. Lips fleshy and without ciliate teeth. Teeth small, uniform in 3-5 rows on jaws. Tip of the tongue rounded or subtruncate. Gill membranes fused to isthmus, branchiostegals 5. Scales ctenoid 26-38 on lateral line, smaller and less markedly ctenoid anteriorly and extending to eyes; feeble on chest. Ventral fins completely united 1.5 + 5.1 not fused to body. Pectorals without free rays or muscular bases. Dorsals separate, often wide apart VI 1.6-9; anal 1.6-8.; caudal variable in shape, longer or shorter than head. A genus of small fishes, usually found in fresh water although at least one species is marine.

Vaimosa valigouva sp. nov.[1]

The description of this species is based on two specimens taken in a fresh water pond on the north coast of Ceylon. Dr. F. P. Koumans of Leiden Museum, to whom the specimens were referred, considers the specimens related to *Vaimosa villa* Herre. Comparison of these specimens with Herre's description and figures in *Gobies of the*

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[1] ' Valigouva ' is the Sinhalese term for *Glossogobius giuris*.

Philippine and China Seas 1927 shows that the two differ in the shape and size of the dorsals, anal and caudal fins, as well as in colour and in the number of scales.

In *Vaimosa villa* the dorsals are remote from one another, the anterior and middle spines of the first dorsal are the longest and do not reach the second dorsal when depressed. The second dorsal and anal have their posterior rays the longest, but the tips of both fins are remote from the caudal which is elliptical and somewhat pointed. Scales LL 38, L tr 12, predorsals 18.
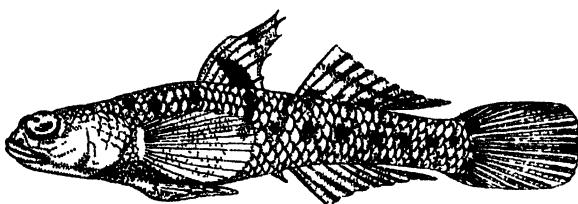
P. Deraniyagala del.

Fig. 1.   *Vaimosa valigouva* sp. nov. × 3

Description.   I D. VI-VII, II D 1.7-8, AI.7-8, P16-17, V I. 5 + 5 I C 15.

Head moderate, slopes upward from the protuberant eyes towards origin of first dorsal, snout short, bluntly rounded. Lips, moderate, angle of gape under mid-eye. Two or three rows of cephalic sensory papillae on cheeks and opercle, teeth in four subequal rows on jaws. Head 8-3.5. eye 3.6-3.9, interobit 0.9, snout 0.7-0.8, depth 4.15-4.25.

Body subcylindrical, feebly depressed anteriorly and feebly compressed posteriorly. Caudal peduncle 1.4 times its least depth. Scales ctenoid, smaller anteriorly. LL 34-35, Ltr. 15, predorsals 16-18, scales between dorsal fins 3-4. First dorsal with second, third and fourth spines elongated to reach the second dorsal when depressed; its origin midway between snout tip and end of base of second dorsal. Second dorsal and anal slope posteriorly, their median rays shorter than the anterior. Both fins nearly reach caudal which is as long as head and is subtruncate with rounded posterior corners. Pectoral as long as head without snout and equals ventral which is remote from anal. Length of fish 21 mm. Colours (in alcohol) brownish, with a

lateral row of 9-11 spots connected by diffuse dark bands to as many dorsal spots. First dorsal with an oblique black band across its middle descending posteriorly and with a diffuse dark band at its tip. Second dorsal with three black spots on its base and a diffuse dark median band. Caudal with two round black spots at its base with a smaller diffuse one between. Other fins unmarked.

The two specimens were taken with *Puntius vittatus* Day, in a pool of fresh water about one kilometer from the sea at Point Pedro (Jaffna) Ceylon.

The type specimen which is deposited in the British Museum is 20 mm. long.

Genus Peristedion Lacépède.

Peristedion Lacépède 1802, Hist. Nat. Poiss III. p. 368.

Body covered with bony plates; each generally with a strong spine. Each lacrymal produced into a flat, rostral process. Teeth absent. Lower jaw with barbels, and included by the upper jaw. Gill membranes separate, narrowly connected to isthmus anteriorly. Dorsal continuous or in two parts. Pectoral with the two lower rays separate. Ventrals 1.5 and wide apart.

Peristedion pothumaluva sp. nov.[1]

The description of this species is based on a single specimen taken off the west coast of Ceylon in February, 1927 It differs from the only other known Ceylon species *P.halei* Day (also described from a single specimen taken off Galle in 1883) in having considerably fewer lateral scales [2]. Mr. J. R. Norman, to whom the specimen was referred for comparison with type specimens of the genus in the British Museum, says that to the best of his belief it is a new species allied to *P.moluccensis* and *P.serrulatus* but he admits the possibility of the specimen belonging to a known species, as these fishes tend to vary with age and sex.

After comparison of this specimen with the descriptions and figures of the above forms, I consider the differences enumerated in the following table sufficient to justify the creation of a new species which is here named *Peristedion pothumaluva*. .

[1] Sinhalese *Pothu* = acute, *maluva* = fish.
[2] Lateral line scales in *P. halei* are 34.

	P. pothumaluva	P. serrulatus	P. moluccensis
Dorsal	VII. 15	VII. 22	VII. 16
Anal	14	21	16
Lateral line	29	33	26
Preorbital spines	0	2	0
Post temporal ,,	0	2	0
Opercular ,,	2	1	0
Rostral ,,	1	5	3
Anterior ventral scutes	2 25 as long as wide	2 as long as wide	nearly as long as wide
Length	355 mm.	150 mm.	'a fine, specimen'
Depth of sea	50 fms.	—	140 fms.
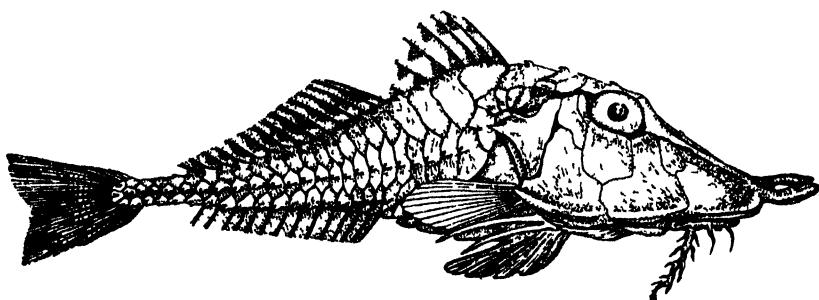
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Fig. 2.   *Peristedion pothumaluva* sp. nov. × ⅓

Description.   Gill rakers 18, short spinose; Br.VII. D.VII. 15, A 14, P 12 + 2, V 1. 5, C 12.   Head large; snout depresed, rising gradually to the eyes, with a single small spine on its upper third between the prefrontal scutes.   Scutes of snout and cheeks form a sharp, lateral ridge above mouth and branchiostegals.   Lacrymal processes tending to converge.   The length of each contained three times in distance between its base and orbit.   A ridge extends from eye to inner side of base of lacrymal process to which area each nasal scute extends as an elongate process.   Interorbit feebly concave, forehead convex. A single supraorbital spine which is larger than the rostral one, exists on the posterior half of each frontal scute.   This scute is 1.75 times as long as the parietal scute.   The latter carries one or two spines and is emarginate posteriorly.   Two spines on lower edge of preopercle. the anterior vestigial, the other strong and forming the posterior angle. Opercle with two sharp spines at its posterior angle, the lower the stronger of the two.   Suborbitals four, the second the largest and bent angularly to form part of the supra-oral ridge.
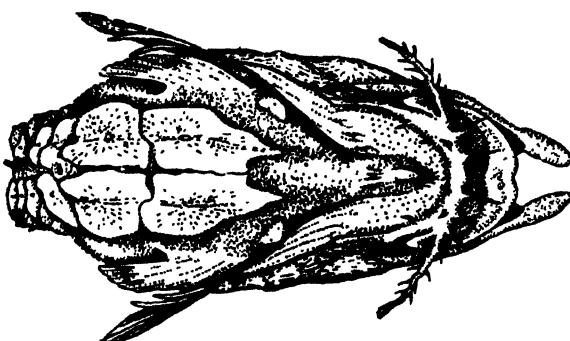
P. Deraniyagala del

Fig. 3. *Peristedion pothumalura* ventral scutes ' × ⅔

Head 2, its width 1.85 in its length; eye 5.9; interorbit 0.9; snout twice as long as post-orbital part of head; mouth U-shaped, width 1.5 times length. Two mandibular barbels, with about six pairs of barbules on each, reach as far as the bases of the branchiostegels. Four shorter, simple barbels between the two mandibular barbels and behind these a row of about eight small ones in an irregular series.

Body short, fusiform, with a naked triangular patch of skin under each pectoral; tail comparatively slender and polygonal in section. Scutes strong and rugose, arranged in four rows on each side, namely, a dorsal row of 24, a lateral row of 29 forming a curved series above the gill-slit, an infra lateral row of 20 commencing beneath the ninth scute of the lateral series, and a ventral row of 19. In the latter series the anterior three pairs are enlarged, the first two being abdominal and carinate and the third pair sub-caudal. The first pair of abdominal scutes are elongated to 2.25 times their width and possess an anterior process. The second pair are wider and shorter, the length slightly exceeding the width, while the third pair, or first sub-caudals, are much wider than their length. All body and some cephalic scutes are armed with a simple spine except the last nine of the lateral row, which have bifid spines and the first and second of the ventral row, which are carinate and spineless.

First dorsal fin nearly separate from second dorsal. Longest spines of former are the third and fourth which are contained 4.9 in head length. Pectoral as long as head minus snout, and reaching to between ninth and tenth lateral line scutes. Two free pectoral rays, the upper the longer of the two and contained 1.4 in length of fin. Ventral

shorter than pectoral, reaches middle of second pair of abdominal scutes. Caudal gently emarginate, the upper lobe a little longer than the lower, 2.9 in head length. Cloaca closer to caudal fin than to tip of lacrymal by a distance equal to postorbital length of head. Standard length of specimen 855 mm. Colour bright scarlet with iris, dorsal, anal and caudal fins, orange. A double row of scarlet spots on first dorsal, one row on second dorsal; skin under pectorals orange.

The specimen was brought from Moratuwa (west coast) on February 21, 1927. It was taken on a line in water said to be 92 metres deep. The holotype is deposited in the British Museum.

Some Postnatal changes in the Leathery turtle Dermochelys coriacea

BY

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(With Five Plates and Four Text Figures.)

The luth or leathery turtle *Dermochelys coriacea* (Linné), the most interesting member of the order Testudinata, is generally described as clawless, with a corselet raised into seven dorsal and five ventral longitudinal ridges which apparently assist in stream-lining. One of its most remarkable postnatal changes is that, although the young are covered with small lizard-like scales, the adult is more or less smooth skinned. Each corselet ridge of the young animal is covered with a single row of scales which are about twice as large as elsewhere upon the corselet. The latter run in four or five longitudinal series between each pair of carapace ridges and in five to seven series between each plastral pair.

Although there are no scales on the corselet of the adult, dissection reveals a mosaic of osseous platelets on the back and sides which corresponds to the infantile scales in general arrangement, namely, the ridge platelets are larger than those of the interspaces and more or less uniserial. Moreover it is seen that these platelets lie immediately beneath the melanophore layer [1] and are very superficial. In an adult female, with a carapace length of 1,590 mm. along the curve of the neural ridge, the thickness of the dermal carapace was 36 mm. while that of the platelets and cuticle was together only 5 mm.

The dorsal mosaic always consists of small, flat platelets traversed by uniserial, longitudinal rows of much larger carinate ones which occupy the ridges. These carinate platelets are ten to twelve times as large as those upon the interspaces which lie in ten to thirteen longitudinal rows between each pair of carapace ridges. Upon these

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[1] Dr. Walter Koch of Vienna kindly sent me some sections of the carapace and drew my attention to this feature.

ridges one or two smaller flat platelets generally lie between every two or three of the larger carinate ones and thus break up the ridge into a series of knobs.

The plastral platelets have disappeared more or less completely except for traces of an inframarginal mosaic and of carinate platelets on the ridges. There are none on the epiplastral region and as the vestiges upon each ridge are interrupted by numerous gaps, it is evident that the missing ones are the smaller platelets which separate the large carinate ones.

Two theories have been advanced to explain the relationship between the corselet scales and bony platelets. The one suggested that the scales multiplied with age and that the platelets were their osteoderms; the other maintained that the platelets arose by secondary proliferation of the marginal bones, after the remainder of the bony corselet which was once thecophoran, had disappeared. Both theories maintained that the platelets of *Dermochelys* were subject to proliferation, but hitherto no young specimen has survived sufficiently long to disclose what really occurs.

It is now possible to describe the actual process of scale disappearance and platelet development in this rare and unusual animal. The material on which the following description is based consists of (1) a brood of young hatched at Bentota on August 12, 1933, of which one individual (A) lived for 662 days while the others died at younger stages; (2) a specimen (B) captured at sea by fishermen on September 30, 1934; and (3) a specimen (C) which was hatched at Bentota on April 23, 1934, and lived for 169 days. Accounts of (B) and (C) are interpolated in the description of specimen (A) and appear next to such growth stages of (A) which by reason of size or age appear to be immediately prior to (B) or (C). This procedure is adopted in order to compare these other specimens whether wild or reared in captivity with specimen A and others of this brood.

DEVELOPMENT.

August 12, 1933. The newly hatched young, including turtle (A), were taken as they emerged from the nest (Plate XXV). The carapace length ranged from 58-60 mm. The turtlets were wrinkled and skinny but after four or five days when the skin had extended and had spread apart the hitherto closely packed scales they assumed the beaded appearance fully described in an earlier paper (Deraniyagala 1932). A conspicuous feature was the black pigmentation of the plastral interspaces.

August 29. Age 18 days. The dermal area covered by each corselet scale was constricted into a boss-like prominence which occupied the centre. These bosses enhanced the tuberculate appearance of the animal (Plate XXVI).
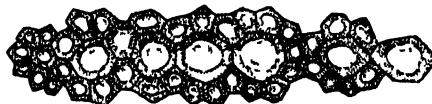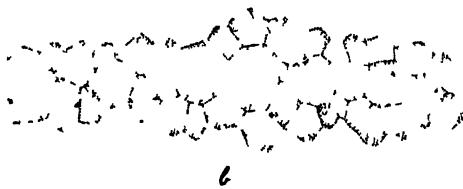
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Fig. 1. a. Plastral ridge of 18 day old *Dermochelys* showing scale bosses before ecdysis × 4
          b. A plastral ridge soon after ecdysis × 8.5

The scales upon the corselet ridges were becoming subquadrangular; those upon the interspaces polygonal. The anterior marginal scales of each flipper had begun to enlarge and those over the tips of the second digits had developed pits by excrescence. A vestigial claw is at times present on one or both of these digits in mature embryos. The plastron projected slightly beyond the vertical level of the carapace.

September 2. Age 22 days. Length of carapace 70-75 mm. Ecdysis had commenced from near the centre of the plastron and was spreading outwards and upwards.

Specimen (B) (Plate XXVI) captured by fishermen at 10 P.M on September 30, 1934, in water 50 m. deep at a distance of 20 kilometres from land and about 2 kilometres from the edge of the continental shelf, examined next day, showed the following features: length of carapace 85 mm., no rostral caruncle, scales wanting from top of head; other cephalic scales widely separate; fore-flippers scaleless except for the anterior margin and an incomplete row above each digit; corselet scales of ridges and interspaces with a central polygonal boss capped with a scale; greater part of plastron scaleless; tips of fore limbs comparatively pointed.

The incomplete ecdysis together with the carapace length suggest the age of the animal as about three weeks. The locality of capture is of special interest as it indicates the presence of the newly hatched *Dermochelys* in water beyond the reef [1] near the edge of the continental shelf.

September 9. Age 29 days. Two specimens only, which were reared apart from others of the Bentota brood survived. In the one the cephalic and plastral scales and some from the carapace and flippers had disappeared. In the other, the cephalic scales were present but the greater part of the corselet was scaleless. The scaleless dorsal areas were a dark leaden-grey in contrast to the deep black of the scaly areas.

September 12. Age 32 days. Length of carapaces 85 and 89 mm. With the exception of a nuchal patch, there were no conspicuous scales upon the corselet which now displayed a net-work of scale boundaries. The colour of the animal was a purplish indigo-blue dorsally with dark brown plastral interspaces. With the death of one of these specimens the account which follows refers to the survivor which is termed specimen (A).

September 26. Age 46 days. Length of carapace 102 mm. The head and corselet possessed a smooth oily appearance although the scale marks were well defined. There were twenty-two protuberances along each median plastral ridge, each of which arose from a single scale and represented a platelet. The white spots on the anterior and posterior of the carapace had begun to enlarge. Each occupied a single scale area. The tips of the flippers were becoming more pointed.

November 10. Age 91 days. Length of carapace 137, mm. The gular and gluteal scales were granular. The scale boundaries on the carapace ridges were hexagonal (c.f. with Aug. 29) protuberances were present on all the plastral ridges, those upon the median pair being the most prominent. There was a large protuberance at the posterior end of each humeral ridge.

January 15, 1934. Age 157 days. The white dorsal pigment was very pronounced, but this was possibly the result of a sheltered environment and comparative lack of sunlight, as specimen (B) showed but little relative increase of white pigment, and specimen (C) which was daily exposed to sunlight for a few hours, possessed less white dorsal pigment than A when of similar age.

Specimen C. Age 169 days. This individual was hatched at Bentota on April 23, 1934, and died on October 8, 1934. It attained

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[1] Hitherto the area inhabited by the newly hatched young was unknown.

the following dimensions: total length 205 mm., carapace length 160 mm., plastral length 133 mm., axilla to groin 78 mm., head length 40 mm., extended forelimbs, tip to tip 280 mm. The head possessed a domed vertex. All the scales were flat but distinct. The fronto-parietal was longer than the parietals and the scales of the epiplastral area were enlarged. Each of the five inner carapace ridges possessed a row of white spots which were most distinct upon the supramarginals, while the spots upon the marginals were confluent. Scattered, indistinct white spots occurred upon the interspaces, each occupying a single scale. The two median dark bands on the plastron were more reduced than the external ones.

The corselet ossification was examined in a transverse section taken across the middle of the animal's right side. This section occupied three scales of each of the marginal and supramarginal ridges and contained a portion of the carapace and plastron as well as part of a rib. The osseous structures were stained in alizarin and potash, and the section cleared in glycerine.
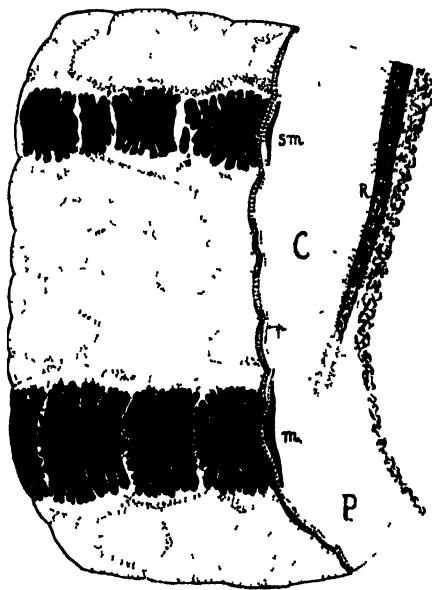
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Fig. 2. Alizarin stained transverse section across middle of right side
of 169 day *Dermochelys* × 2.5

C, carapace; P, plastron; R, rib; m, marginal platelets; sm, supramarginal platelets; p, melanophore layer.

The preparation showed that only the ridge platelets had ossified and of these, the marginals were more developed than the supramarginals. Each platelet was roughly stellate, the processes being least conspicuous along the anterior and posterior margins. The marginal platelets were wider than their ridge scales and had commenced to form sutural connexions with one another (Fig. 2 m.). The supramarginal platelets were smaller than these platelets, narrower than their ridge scales and separate from one another. Their anterior and posterior margins were also more regular than those of the marginal platelets, which were subequal. Following each of the supramarginals were one or two smaller platelets (Fig. 2 sm.), but it is possible that this feature is variable in different parts of the same ridge. The relative position of these osseous platelets to the scales is now definitely known. The ridge platelets did not disclose any restriction by the ridge scales, except that they were nearly as completely uniserial as the latter. Two or three platelets usually lay under each scale and frequently each terminal platelet extended beneath the adjacent ridge scale. No platelets were discernable upon the interspaces between the ridges, and it is probable that they do not appear until the ridge platelets are more or less completely sutured.

The position of the rib is also of interest. In both adult and young it is separated from the platelets by a thick dermal carapace. Upon the outer surface of this structure the platelets lie comparatively superficially immediately below the melanophore layer (Fig. 2 p.). Upon the internal surface of the dermal carapace, the greater part of the rib also lies superficially; but when the latter reaches to above the marginal row of platelets, its distal tip enters the dermal structure to some depth (Fig. 2 R). In Thecophora this tendency has reached its final development and many of the rib tips fit into hollows in the marginal bones.

February 22, 1934. Age 195 days. Specimen (A). Length of carapace 225 mm. The bony ridge platelets were visible through the skin and the anterior and posterior limits of each were defined by a white margin. Under each pair of enlarged ridge scales were five or six platelets which were most distinct upon the marginal ridges. A solid white line of fibrous consistency separated the two median plastral ridges from each other.

March 17. Age 218 days. Length of carapace 302 mm. Weight 8,005.1 gm. (6 lb. 10 oz.). The scale marks were best defined upon the head and margin of the plastron. Those upon the corselet had become more indistinct. The scales on the neck, limbs and tail were distinct and those along the anterior edges of the flippers were noticeably enlarged. The top of the head was somewhat domed, while the
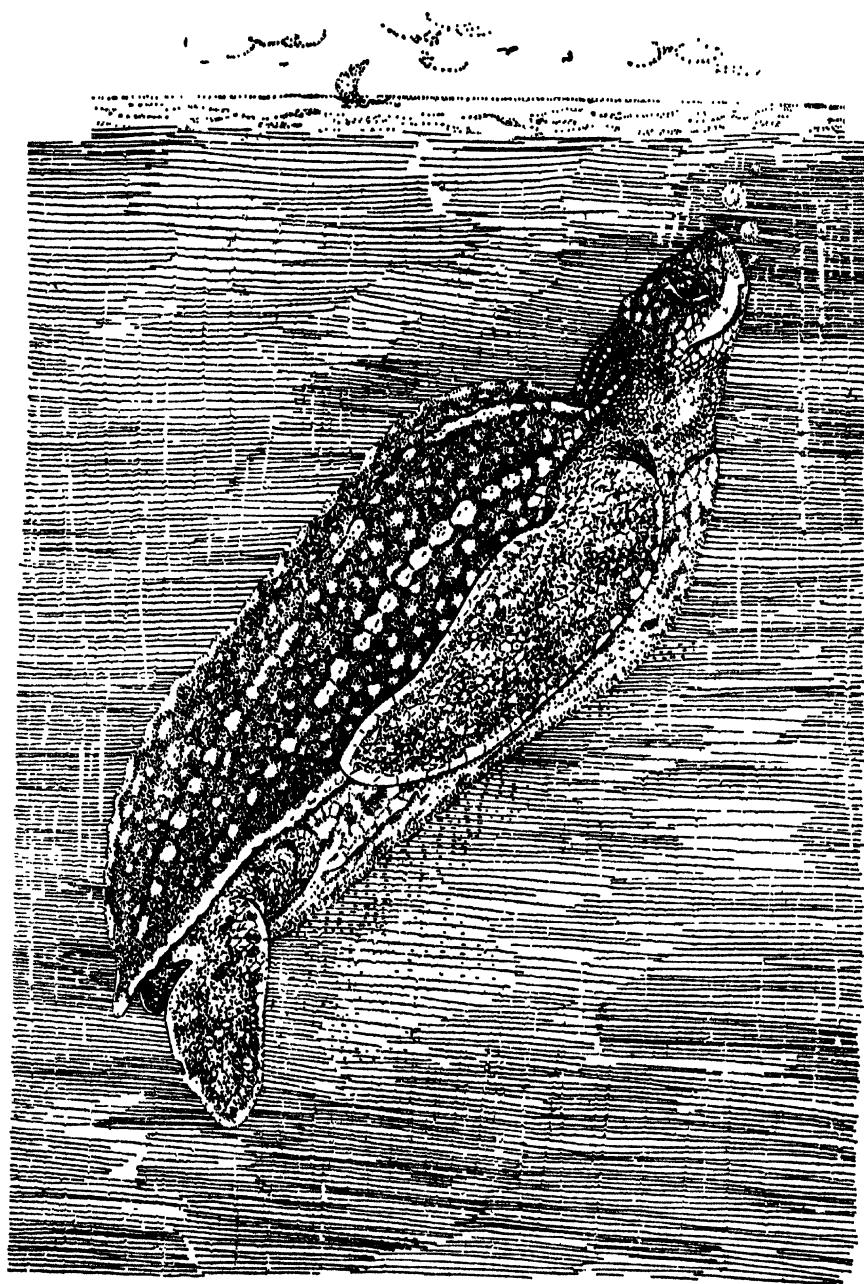
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Fig. 3. A 232 day old *Dermochelys coriacea* × ½

scales of the parietal and supraocular areas were relatively more elongate than the frontoparietal, which in most specimens is a large azygos scale.

June 15. (Plate XXVII.) Age 308 days. Carapace length 350 mm., weight 4,536 gm. (10 lb.). Scale marks were present upon the head and limbs, but those of the corselet were less distinct. Their vestiges were most conspicuous on the anterior and inframarginal parts of the plastron. A cruro-caudal fold of skin was developing between the hind limbs and tail.

March 6 (1935). (Plate XXVIII.) Age 624 days. Length of carapace 433 mm., weight 6,804 gm. (15 lb.). Scale marks were as follows : cephalic scale marks most distinct on top of snout and around eyes; those in parietal region conspicuously elongated, and longer than fronto-parietal; carapace scale marks and those above digital terminations of flippers very indistinct; scales on remaining parts of limbs and tail distinct; plastron scale traces indistinct, especially anteriorly. The corselet mosaic was better developed.

Ridges. Dorsally the neural ridge was divided into seven sections by cross folds of skin each section being as long as post-orbital part of head and comprising several tubercles. There were twenty-five tubercles along this ridge arranged into sections separated by gaps; the number of tubercles in each consecutive section were as follows :— 5-2-2-2-3-10-1. The tubercles on the other ridges were also uniserial and interrupted. The marginal ridge comprised twenty-five tubercles, the supramarginal twenty and the costal twenty-six. The bases of the neural as well as the costal ridges presented a swollen appearance due to ossification. A translucent osseous mosaic occupied the upper third of the inframarginal area. The plastral ridge tubercles were as follows : left inframarginal five, left humeral eight, left median eleven, right median twelve, right humeral seven, right inframarginal five. The two axillary pores were anterior to the bony mosaic and situated on the dermal part of the corselet. The second pore was under the second marginal tubercle.

Colours. Dorsally, head black, blotched with white, the edges of the upper beak behind each premaxillo-maxillary cleft black. The neck with five uniserial rows of white spots the median row with a bifid posterior end. Interspaces scattered with similar spots. Anterior three quarters of each carapace tubercle white, three longitudinal rows of white spots above each costal ridge, four on each of the four interspaces below these ridges, marginal tubercles white. Limbs black, outlined with white and spotted with white, the posterior limbs darker than the anterior.

Ventrally, white, with a few dark spots at base of neck. A single row of black spots between median and humeral ridges of plastron, a double row between humeral and inframarginal ridges, and a single row of much larger blotches inframarginally. The two black streaks which bound the perineal area were interrupted anteriorly. Tail with a broad black dorsal band below a thin white margin. A black band passed transversely under tail and across the cloacal opening.

Growth of *Dermochelys coriacea*

Date.	Age in days.	L. of Head.	L. of Carapace.	W. of Carapace.	L. of Plastron.	L. of Bridge.	Arms tip to tip.	Plastron to Cloaca.	Weight in Gm.	Number of Turtles.
Turtle A										
1933.										
Aug. 12	1	24	58–60	36	—	28	—	—	{ 32.62 to 33.57	10
Sept. 2	22	25–27	70–75	50–53	—	—	—	—	—	10
,, 12	32	27	85	55	—	—	—	—	—	1
,, 12	32	27	89	58	—	—	—	—	—	1
,, 26	46	27	102	63	—	50	—	—	—	1
Nov. 10	91	32	137	82	—	—	231	18	—	1
1934.										
Feb. 10	183	48	254	—	—	—	—	—	—	1
,, 22	195	54	255	155	2?4	128	388	18	—	
Mar. 2	203	—	—	—	—	—	—	—	2438.1	
,, 17	218	60	302	176	260	155	450	24	3005.1	1
,, 22									3061.8	
June 15	308	61	350	—	300	160	540	37	—	1
July 21	344	66	356	—	—	—	—	—	—	
Nov. 20	466	—	368	212	305	170	580	48	4536	1
1935.										
Mar. 6	562	80	433	235	345	190	620	49	6804	1
,, 24	586	80	433	235	345	—	650	—	7257.6	1
April 30	624	84	435	240	345	200	670	50	7265	1
Turtle B										
Oct. 1, 1934	21	29	85	60	80	46	180	11	96	1
Turtle C										
Oct. 8, 1934	169	40	160	90	133	78	280	20	—	1

June 7, 1935. Age 662 days. Specimen A died as a result of its water supply being contaminated with sewage. Its dimensions were as follows : total length 545 mm., length of carapace 420 mm., extended arms, tip to tip 680 mm., length of frontoparietal scale 15 mm., length of parietal scales 22 mm. It is possible that the decrease in size was partly due to sickness and partly post-mortem. Externally the animal was but little different from its description at 624 days although the carapace was depressed owing to ill-health.
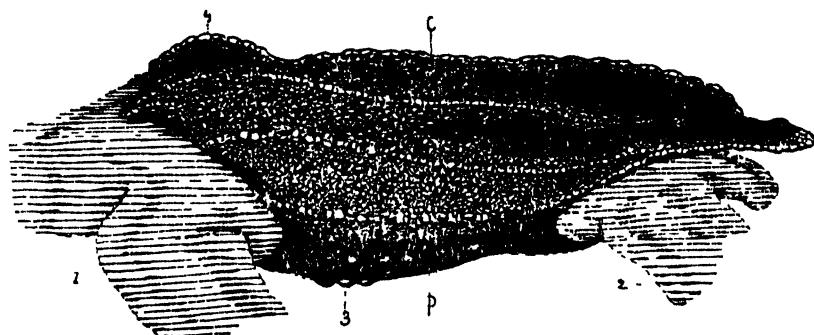
Fig. 4. Bony corselet mosaic of 662 day old *Dermochelys* × ⅓

1 fore limb, 2 hind limbs, 3 humeral ridge, 4 nucho-scapular hump, C carapace, P plastron; black, dermal corselet; white, platelets; horizontal lines, extremities.

The progress of the developing corselet platelets was examined by dissection. It was seen that the anterior margins of the two interspaces between the marginal, supramarginal and costal ridges were devoid of platelets as in the adult (Deraniyagala 1934, Plate XVII). Otherwise the marginal platelets were complete. The plastral ridges possessed their complement of platelets as did the corselet bridges. The carapace mosaic however was still incomplete. The arrangement of the platelets on each side was as follows: the marginal and supramarginal ridges, together with their interspace, were completely covered with platelets, which were also continued ventrally to cover about a third of the width of the interspace between the marginal and inframarginal ridges and comprised six or seven longitudinal rows of platelets. The inframarginal ridge is seen in Fig. 4, as a row of four separate platelets. The costal row extended to above the base of the tail. The posterior third of the interspace between this ridge and the supramarginal was not bridged by platelets. The bony neural ridge extended further back than the costal but did not reach the supracaudal margin. Both its anterior and posterior ends were recurved. The areas devoid of platelets between the costal and neural ridges consisted of an oval patch located anteriorly on the nucho-scapular hump and the posterior two-thirds of the interspace. The only place where this interspace was completely bridged by platelets was its anterior edge. Two conspicuous isolated patches of platelets, which appeared to be interrupted continuations of the costal and neural ridges respectively, were present between the terminations of these ridges and the margin.

The interspace platelets had probably been in existence for some length of time. Attention has already been drawn to the swollen bases of the carapace ridges in the 624 day old specimen. These thickenings were now seen to have originated through development of the smaller interspace platelets along either side of the rows of ridge platelets. Dissection of the 662 day old animal showed that these smaller platelets bordering the enlarged rows (see Fig. 2) increased their numbers, and ultimately met similar ones from the bases of other ridges.

In this manner the greater area of the interspaces was bridged over by platelets anteriorly. Posteriorly platelet development was comparatively slow and gaps separated the rows of ridge platelets which were here bounded laterally by only two or three rows of smaller platelets. It was also seen that about six to ten of these interspace platelets were covered by each interspace scale. It is possible that primitively each scale covered only a single platelet, but that gradually the scales enlarged and reduced their numbers at a faster rate than their osteoderms. It has already been shown that the corselet scales do not proliferate (Deraniyagala 1932), but the development of the interspace platelets might be regarded by some as proliferation from the enlarged ridge platelets. However against such a view is the distinctness of each platelet, the independent origin of all rows of ridge platelets, which primarily are widely separate. It is further seen that what appear to be interrupted portions of these rows are also of isolated origin. Both features suggest that the athecan corselet cannot be derived by proliferation of the marginals, although the proliferation theory (Versluys 1913) is the nearest description of what actually does occur during the growth of this remarkable animal's osseous corselet.

SUMMARY

Scales. This study of the growth changes in *Dermochelys* showed that the infantile scales reached their limit of expansion when the turtlet was about eighteen days old. Each scale then commenced, to constrict the skin beneath into a polygonal boss [1]. Ecdysis of these strong, infantile scales began about the twenty-second day and ended about the forty-sixth, leaving the animal covered with a network of scale marks which altered in outline especially upon the corselet ridges. The scales themselves were but feebly renewed as a comparatively fine cuticle which was shed in patches, at intervals. The shed skin showed scale boundaries which became more and more indistinct with age as the majority of scales thinned out and disappeared, leaving the adult

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[1] An analogous process occurs in the young of the marsh crocodile *Crocodylus palustris.*

comparatively smooth skinned. However, vestiges of scale divisions and bosses are sometimes discernable upon the eyelids, neck and caudal crest of the adult (Plate XXIX).

Platelets. The first indication of osseous platelets occurred when a uniserial row of tubercles appeared upon each corselet ridge; later, the rudiments were visible through the cuticle, in the 157 day old animal. At this stage there were no platelets upon the interspaces. The marginal platelets were both larger and closer to one another than those of the supramarginal ridges. In the 308 day turtle transverse folds of skin interrupted the carapace ridges into lengths each containing several platelets and in the 562 day animal the corselet mosaic had extended some distance down each bridge. It is probable that by now the platelets of the interspaces had begun to develop on either side of all carapace ridges, for in the 624 day specimen the base of each ridge appeared swollen. In the 662 day specimen, with the exception of a patch on each side of the nucho-scapular hump, and on the posterior parts of the two interspaces above the supramarginal and costal ridges the platelet mosaic of both carapace and plastron was numerically complete (Fig. 4). It is of interest to note that this process was achieved at a considerably earlier date in the plastron than the carapace. The plastral platelets were probably numerically complete in the 169 day old animal, whereas the carapace mosaic was incomplete in the 662 day old animal. As soon as ossification was complete upon the carapace ridges their scale traces disappeared and it is evident that the animal becomes smooth skinned soon after the osseous mosaic is completed.

Plastron and Extremities. The plastron commenced to project beyond the vertical through the front of the carapace, about the time the animal commenced ecdysis, viz., when eighteen days old. When the animal was about one year old, the anterior edges of both carapace and plastron were again at the same vertical level; thereafter the carapace overlapped the plastron to a small degree. The limbs also altered in outline and proportions and their tips gradually became more acute. The 308 day old animal showed a moderate cruro-caudal fold of skin with a relative increase in the distance between the plastron and cloaca. These features are all conspicuous in the adult, the last reaching its maximum development in the male when the tail undergoes secondary sexual elongation (Plate XXIX).

Pigmentation. Towards the forty-sixth day the white dorsal spots and bands appeared comparatively enlarged and more or less retained their proportions until the animal was 600 days old. Thereafter they

commenced to decrease. It is probable, that in the present instance, the slow disappearance of white dorsal pigment is due to the comparative lack of sunlight, for the animal was kept in a shed. It is suggested that under natural conditions this pigment will probably diminish at a faster rate, as the animal floats at the surface exposed to sunlight. Since no adult has yet been noted with white bands upon the carapace ridges, the loss of these marks is probably correlated to the assumption of secondary sexual characters. In the adult, the white spots of the carapace decrease considerably in size, but generally persist upon a slaty background surrounded by diffuse black polygons (Plate XXIX) which denote the former boundaries of the polygonal infantile scales. Ventrally the broad black bands, so conspicuous in the newly hatched (Plate XXV) soon diminish, and eventually might only persist as a feeble reticulation upon the bridges and parts of the plastral margin. The white spots upon the ventral surface of the neck, limbs and tail enlarge and fuse to form large areas more or less reticulate with black, which generally fades with increasing age and eventually disappears.

Secondary Characters. Adults are comparatively smooth skinned although scale traces may persist upon the eyelids, neck and caudal crest. The scale truces do not disappear until after the completion of the corselet mosaic of platelets. The fore-flippers develop acute tips and the posterior pair are subtriangular. Connecting the hind limbs and tail is a strong cruro-caudal fold of skin. The white dorsal bands of pigment persist upon the head, neck and caudal crest, but disappear completely from the carapace ridges. The plastron is either entirely white, or possesses a dark reticulation along the margins. The general outlines of the adult female are more or less akin to those of the adolescent (Fig. 3) but the male (Plate XXIX) displays stronger differentiation in possessing a concave nasal profile, domed skull, comparatively depressed body and elongate tail.

Three changes commence ventrally, namely, loss of black pigment, platelets and scales. It is evident that sunlight is an important factor in the first, while it is very probable that the ventral loss of platelets is also thus influenced.

CONCLUSIONS

Scales. Ecdysis suggests that in the Atheca, scale changes commence ventrally. In Thecophora such as *Eretmochelys imbricata* (Linné), the first imbricate scutes to become juxtaposed are the plastrals, consequently it is suggested that in the Testudinata, changes in scales or scutes commence ventrally and spread dorsally.

Platelets. The first platelets to appear are those upon the widely separated ridges (Fig. 2). Hence the view that the corselet mosaic is derived by proliferation of the marginals is untenable. Extinct and living Atheca show that this mosaic is disappearing ventrally. The plastral vestiges of *Dermochelys* suggest that in the evolution of a structure or similar structures the first to appear (*e.g.*, the ridge platelets) are the last to disappear. It is possible that the loss of platelets will parallel the course of ecdysis and might eventually be as complete.

Ribs. The rib ends show a tendency to reach the marginal platelets. In Thecophora this process is complete and is a character peculiar to the order Testudinata.

Corselet. The relatively less specialized position of the marginals and rib ends in Atheca, and the occasional persistence of two or three neurals in a transverse series in Thecophora, suggest that the thecophoran corselet is derived from the athecan.

Colour. Black pigment increases dorsally, decreases ventrally. Sunlight is an important factor in these changes.

Habitat. Dermochelys is more oceanic than any other turtle. The young frequent water near the edge of the continental shelf. The next time they cross the reef is probably when coming ashore to lay.

I wish to express my thanks to Mrs. E. Tillekeratna for procuring all the Bentota specimens mentioned in this paper and to Mrs. A. H. E. Molamure for the trouble taken in rearing specimens (A) and (C) which required frequent changes of sea water daily and careful attention to diet whenever signs of indisposition were displayed.

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EXPLANATION OF PLATES

Postnatal development of *Dermochelys coriacea*,
(Photographs)

PLATE XXV—*Dermochelys coriacea*, newly hatched × $\frac{7}{10}$
Fig. 1.—Dorsal view
Fig. 2.—Ventral view

PLATE XXVI—Ecdysis in *Dermochelys coriacea* taken at sea × ½

   Fig. 1—Dorsal view

   Fig. 2—Ventral view

PLATE XXVII—*Dermochelys coriacea*, born Aug. 12, 1933 × ½

                 Photographed November 10, 1934.

   Fig. 1—Dorsal view

   Fig. 2—Ventral view

PLATE XXVIII—*Dermochelys coriacea*, born Aug. 12, 1933 × ⅓

                 Photographed May 27, 1935.

   Fig. 1—Ventral view showing scale marks

   Fig. 2—Lateral view

PLATE XXIX—*Dermochelys coriacea*, adult male netted on June 11, 1930, off
           Colombo × $\frac{1}{18}$

1.

2
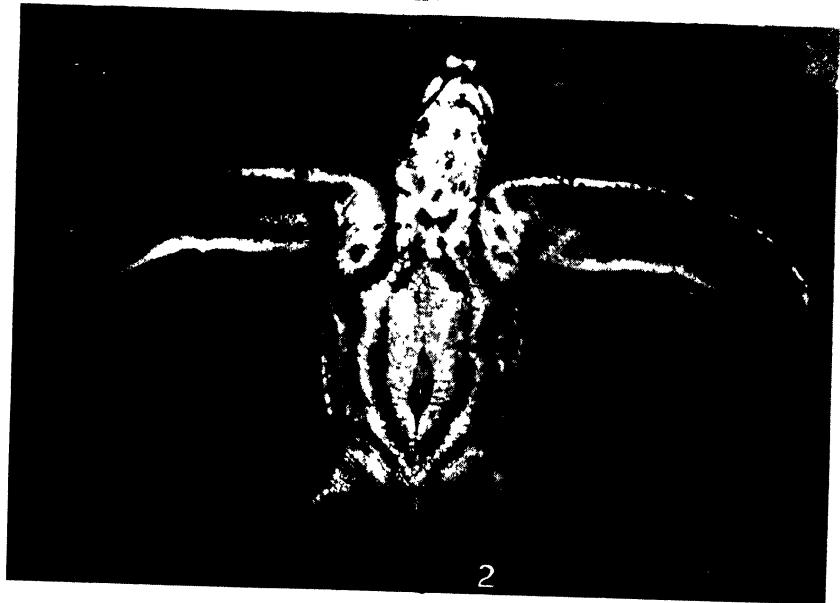
Dermochelys coriacea (newly hatched)
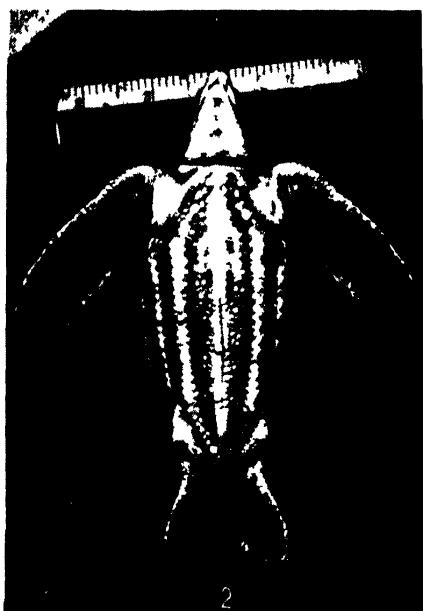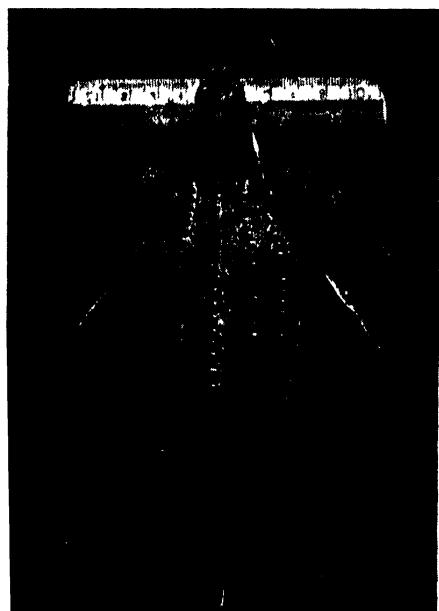
Ecdysis in Dermochelys coriacea × ⅓
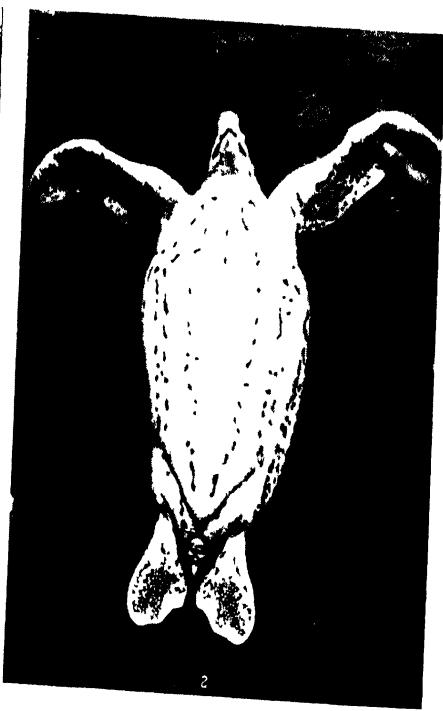
Dermochelys coriacea (age 15 months) × $\frac{1}{4}$

2

Dermochelys coriacea (age 21 months) × ⅛
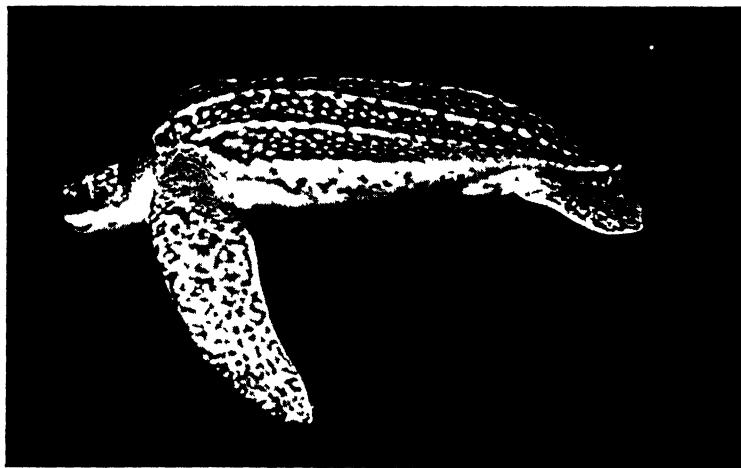
Dermochelys coriacea (adult male) × $\frac{1}{15}$

A further comparative study of Caretta gigas

BY

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(With Four Text Figures.)

The original description of *Caretta gigas* was published in 1933, but, for reasons stated in footnote on p. 69 of that paper, it is now proposed clarify further to the systematic status of this species by comparison with *Caretta caretta* (Linné) and *Lepidochelys olivacea* (Eschscholtz).

/// = LEPIDOCHELYS.
⊕⊕. = COLPOCHELYS .
✱✱ = CARETTA CARETTA
OO. = CARETTA GIGAS

P. Deraniyagala del.

Fig. 1. Map showing world distribution of Carettidae

The family Carettidae comprises four distinct species separable into three genera (Deraniyagala 1934). So close is the external resemblance among these turtles that many workers, who were only
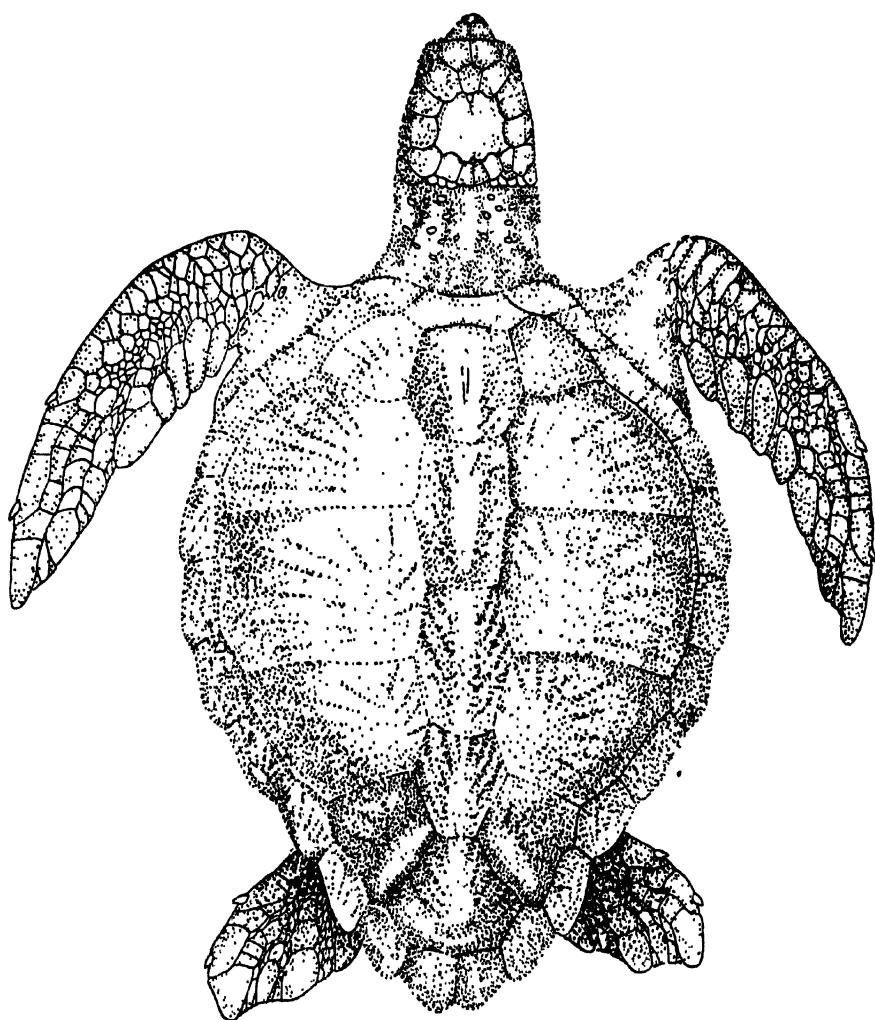
P. Deraniyagala del.

Fig. 2. Adult female *C. gigas* × ¼

acquainted with decolourized museum specimens, recognized but a single species. The features of similarity are as follows: two pairs of prefrontal scales; usually two claws on each limb [1] costal scutes more than four pairs the first contiguous with the nuchal; intergular vestigial or absent and the costomarginal fontanelles disappear in the adult. The genera however differ widely in adult pigmentation; and *Lepidochelys* Fitzinger, has each enlarged inframarginal scute perforated by a pore. In the other genera, viz., *Colpochelys* Garman, and *Caretta* Rafinesque, these scutes are entire.

As might be expected in a family where external appearances are so similar, the species in a genus are not easy to distinguish. In *Caretta*, the only genus not monotypic, the two species *caretta* and *gigas* display a close external resemblance. Few characters are absolutely constant in marine Thecophora, consequently the usual relative position of a scute or bone, as well as their usual total number when in a series are commonly accepted as specific.

The following characters of *Caretta gigas* are based upon twelve carapaces as in the following table.

TABLE I   Osteology of *Caretta gigas*

Turtle	Neurals	Supra pygals	Isolated Neurals	Contiguous costals	Marginals	Marginals touching ribs
(1)♀	11	3	0	0	12	4-9.11.12
(2)♀	11	2	0	0	12	4-9.11.12
(3)♀	11	2	0	0	12	4-9.11.12
(4)♀	10	3	10.9.8	8.7.6.5	—	—
(5)	9	3	9.8	8.7	13	4-8.10.11.12
(6)	9	3	9	8	12	4-9.11.12
(7)	9	4	9+8.7.6	7.6.5	12	4-9.11.12
(8)	9	3	9.8.7+6+5	8.7.6.3	R. 13 / L. 12	R. 5-10.12.13 / L. 4-9.11.12
(9)	8	3	8	8.7	12?	4-?
(10)	8	3	8.7	8.7	12	4-9.11.12
(11)	7	2	0	8.7	13	4-9.11.13
(12)	7	2	7.6.5	8.7.6.5.4	12	4-9.11.12

Characters of Caretta gigas (Fig. 3).

1.   Rib-ends enter marginals 4 to 9 and 11 and 12.

2.   Neural bones range from 11 to 7, usually 11 to 9.

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[1] *Colpochelys kempi* Garman usually has 3 claws (de Sola et Abrams 1933).

[2] (a) The neural behind the last one to touch the seventh and eighth costals, is the last neural.

(b) In 'isolated neurals' those connected by + e.g., 9 + 3, are in contact with each other.

(c) R = right, L = left.
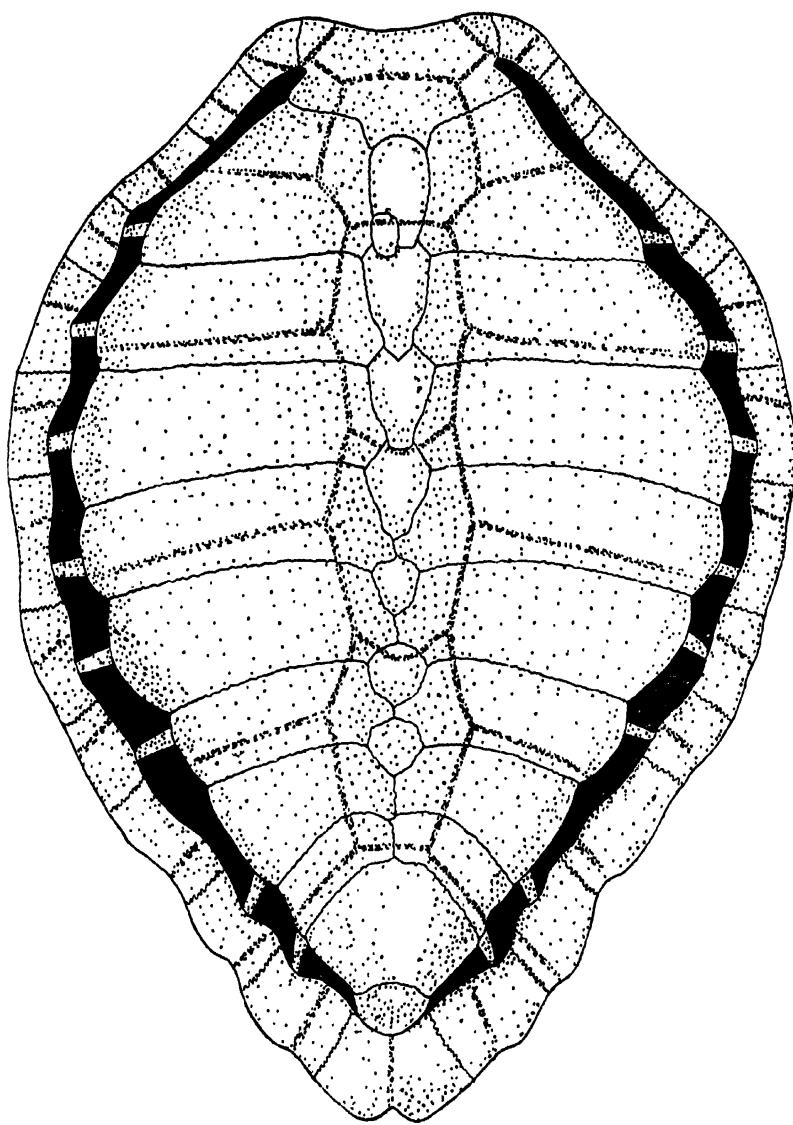
Fig. 3. Bones of carapace (No. 12) × ⅓

3. Generally the vertebral ends of costal bones 8, 7, 6, and 5 of one side are partially or completely contiguous with their fellows of the opposite side. They thereby, either separate from one another, or replace entirely, the intervening neural bones. In occasional specimens the fourth and the third pairs of costals also act in this manner. Of twelve carapaces, the neurals were enterrupted by the costals in eight.

4. The suprapygals are generally 3, sometimes 4 or 2. Of the twelve carapaces examined, seven possessed 3, four possessed 2, and one had 4.

5. The pigmentation of the young is probably of specific value as it differs from published accounts of young *Caretta caretta*. A young specimen sent me from Bundaberg, Queensland with carapace length 45 mm., was pigmented as follows: head reddish-brown dorsally, beaks and cheeks dark brown; neck yellow-ochre with a dark vertebral band; throat as dark as this band; carapace reddish-brown darker between the three ridges than at the margins; flippers dark brown; plastron considerably lighter than carapace with a dark diffuse margin exclusive of infra-marginal scutes, which are coloured like the rest of the plastron. A narrow dark, margin to plastral scutes. Ventral surface of flippers reddish-brown. The other specimen taken from this nest is reported to be similar. The neck pigment and the light plastron are possible features of difference from the uniform dark brown ascribed to the young of *Caretta caretta*.

Characters of Caretta caretta

1. Rib-ends generally enter marginals 3 to 8 and 10 and 11 (Hay 1908, p. 8) but sometimes they enter 3 to 9 and 11 and 12.

    (a) Dr. L. Stejneger of the United States National Museum kindly sent me the following information after examining skeleton No. 78269 of a *C. caretta* with a carapace 910 mm. long which was killed in Virginia ' peripherals entered by ribs 3.4.5.6.7.8.10.11. peripheral 9 not touched by any rib, exactly as described by Cope.'

    (b) Dr. H. L. Babcock of the Boston Society of Natural History kindly examined the only skeleton in his collection and states that ribs enter the junction between the third and fourth marginals, and marginals 5 to 8. The sixth rib enters the posterior half of marginal 9 and others enter the junction between marginals 11 and 12, and the twelfth marginal bone. Neurals 8, the top one being divided.

2. Neural bones range from 8 to 7 (Hay 1908, p. 8).

3. Generally the vertebral ends of costal bones 8 and 7 of one side are contiguous with their fellows of the opposite side. They do not appear to separate any neurals from one another.

(a) Dr. C. R. de Sola of the Tropical Biological Society, Miami, Florida, kindly informs me (May 5, 1934). 'Concerning the four shells here I find that the neurals are uninterrupted by the costals. It is my impression that this is the case in all specimens I have ever seen of Atlantic logger-heads.'

(b) Dr. H. L. Babcock informs me that the single skeleton of *Caretta caretta* in his charge is ' A large adult from the Florida Keys in which the neural bones are *not* separated.'

(c) A dried young *Caretta caretta* from the Mediterranean was examined by me in the Museum of His Highness the Gaekwar of Baroda. The last two pairs of costal bones were completely contiguous at their vertebral ends, the neurals were uninterrupted.

4. Suprapygals generally 2.

It is evident that in the genus *Caretta* the costal bones have begun to replace the neurals. Pleurodirous testudinates display various stages of this process; some genera are in the preliminary stage, viz., the interruption of the neurals by the costals; others lack the posterior neurals, while in yet others, a total loss of neurals completes the process.

In *Caretta gigas* the tendency of the posterior costals to supplant the neurals has spread anteriorly as far as the third pair of costals (Fig. 3), but in *Caretta caretta* it stops at the seventh pair. As *Caretta gigas* usually possesses 11 to 9 neurals, it is evident that the reduction of neurals in *Caretta caretta*, viz., 8 to 7, is due to the last two or three having been replaced by the last two pairs of costals, which are fully contiguous at their vertebral ends. The low number of neurals in *C. caretta*, suggests that this form is more highly specialized than *gigas*. However, the latter also reaches as low a number of neurals although less frequently, but to counterbalance this is the fact that it displays a greater tendency for the costals to replace the neurals, than in *C. caretta* where it is localized posteriorly.

Caretta gigas has been confused so often with *Lepidochelys olivacea*, that comparison of their lepidosis [1] is of interest. The neural bones of the latter occasionally number 15 usually 14 or 13 and rarely 12. The relationship of the marginal bones to the rib tips is as in *C. gigas*.

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[1] Their skulls and carapaces have been discussed elsewhere (Deraniyagala 1933).
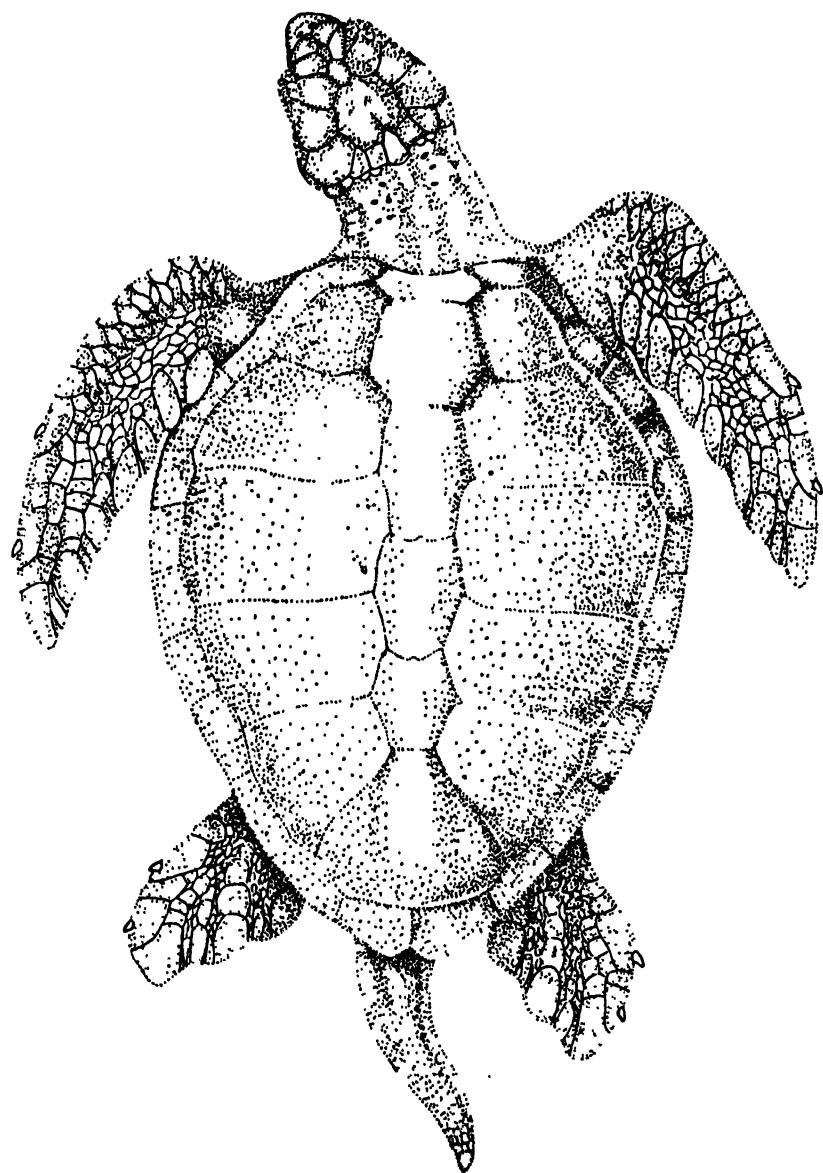
Fig. 4. Adult male *C. gigas* × $\frac{1}{10}$

In adults of the two forms the cephalic scales differ considerably in their relative proportions. In *C. gigas* these scales more or less maintain their infantile proportions except for an increase in the size of the frontoparietal, but in *L. olivacea* the parietals elongate considerably as will be seen in tables II and III. In *C. gigas* the frontal (F) and the parietals (P) are nearly of equal length but each is only about half the length of the frontoparietal (F.P.). In *L. olivacea* the frontal and frontoparietal are almost equal in length but each is shorter than a parietal.

TABLE II   Head Scales of *Caretta gigas* Deraniyagala [1]

	Young	*Adults*		
Locality	*Australia*	*Karaduva* ♀	*Vangalai*	*Colombo* ♀ *Museum* ♀
L of F.	5	31	35	35
L of F.P.	7.5	64	67	77
L of P.	2	32	28	34
L of Hd.	21	187	215	240

TABLE III   Head Scales of *Lepidochelys olivacea* (Eschscholtz)

	Young	*Adolescents*	*Adults*							
Locality	*Maggona*	*Galkissa*	*Karaduva*				*Galkissa* ♀			
L of F.	4.6	4.5	17	14	33	36	35	36	30	33	37	33
L of F.P.	9	9	18	16	30	37	40	33	36	39	44	40
L of P.	3	2.9	15	14	41	33	44	45	45	46	41	45
L of Hd.	21	21	63	62	170	165	172	170	162	170	160	169

In *Caretta* it is also usual to find a well developed interparietal scale which is longer than the parietals it separates (Fig. 4). In *Lepidochelys* this scale usually fails to separate the parietals and is small or wanting. In *Caretta* there are three large mandibular scales on each side, whereas *Lepidochelys* has but one, which is almost as long as a parietal scale. The carapace scutes are the least useful for specific purposes and are largely responsible for the confusion of

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[1] F — frontal, F.P — frontoparietal, P — parietal. L of Hd. — Headlength from tip of upper beak to end of median of parietal scales. Elsewhere in this volume it is recorded that *Dermochelys coriacea* Linné, the most primitive testudinate, undergoes a similar change in the relative proportions of its cephalic scales. Measurements in mm.

species by systematists. *Caretta gigas*, which is brown-red dorsally, usually possesses five pairs of costals whereas *Lepidochelys olivacea*, which is olive-green dorsally, usually has more. The plastral scutes are the most useful for diagnostic purposes. *Lepidochelys* possesses four enlarged inframarginals on each side, and each scute is perforated by a pore near its posterior margin, whereas *Caretta* has only three enlarged, poreless, inframarginals on each side.

The relative width of the adult vertebral scutes also differs in the two forms. In *C. gigas* this width is contained 2.3 to 2.9 times in the widest costal scute with marginal attached, in *L. olivacea* it is contained 3 to 3.5 times.

Characters of systematic value in Carettidae are as follows:—
Generic characters

1. Dorsal pigmentation of adult.
2. Relative length of frontoparietal scale.
3. Relative size and position of interparietal scale.
4. Number of enlarged mandibular scales.
5. Relative width of vertebral scutes.
6. Number of enlarged inframarginal scutes.
7. Inframarginal pores.

Specific characters

8. ? Pigmentation of young.
9. Marginal bones which receive rib tips.
10. Number of neural bones.
11. Suppression of neural bones by costals.
12. Number of suprapygal bones.

DESCRIPTIVE KEY TO CARETTIDAE (ADULTS).

(a) Four enlarged inframarginals on each side

    1. Dorsally olive-green. Each inframarginal with a pore, costal scutes more than five pairs, limbs two or one clawed . . . . *Lepidochelys olivacea*

    2. Dorsally dark grey. Inframarginals poreless, costals five pairs, limbs three clawed . . . . . *Colpochelys kempi*

(b) Three enlarged poreless inframarginals on each side, dorsally brown-red, limbs two clawed

    1. Ribs usually do not enter marginals 1, 2 and 9, neurals 8-7, and uninterrupted . . . . . *Caretta caretta*

    2. Ribs usually do not enter marginals 1, 2, 3 and 10; neurals 11-7, and usually interrupted . . . . *Caretta gigas*

Caretta gigas Deraniyagala, is more completely defined as follows:—

Head with two pairs prefrontal scales, frontoparietal much longer than frontal or parietals. Frontal usually longer than the last. Scutes comprise twelve or thirteen marginals on each side, five pairs of costals, five vertebrals and three enlarged poreless inframarginals on each side. Flippers with two claws on each. Carapace cordate, acute posteriorly and with a serrate posterior margin, the suprapygal region distinctly raised. In the adult male the carapace is elongate and has a smooth margin which is elliptical in outline. The tail of the male reaches beyond the hind flipper (Fig. 4), that of the female barely reaches the edge of the carapace (Fig. 2). The skull is very similar to that of *Caretta caretta;* neural bones 11-7, frequently interrupted or replaced in some places by the costals. Marginal bones 12 or 13 on each side; numbers 1.2.3. and 10 usually not entered by rib tips. When there are 13 marginals, usually number 11 is also untouched by the ribs. The colours are as follows:— (Young) as stated previously. (Adult) brown-red dorsally, light orange ventrally. In the adult the margins of the head scales are broadly outlined in yellow-ochre thereby reducing the brown-red to irregular blotches. Sides of head yellow ochre. Beaks yellow, with a few indistinct dark bands on the sides.

Food; either animal or vegetable. A female had the stomach full of algae; another contained pieces of mollusca, crustacea and sea urchins. Little is known of its reproduction in Ceylon waters. It probably breeds in the Maldives, East Indies, and Pacific Islands. Newly hatched young were obtained from near Bundaberg, Queensland, in the region of the Great Barrier Reef. According to turtle fishermen in the Gulf of Mannar it frequents deeper waters than *L. olivacea.* An adult male was seen 13 kilometers west of Aripu in the Gulf of Mannar (depth of water 15 metres). Another was captured off Madras. Tropical and subtropical; Indo-Pacific.

Before concluding I wish to express my indebtedness to the following:— Drs. C. R. de Sola, L. Stejneger, H. L. Babcock, and A. Loveridge of America for the help mentioned; the Sydney Museum authorities for their kindness in exchanging young of this species for those of *Lepidochelys olivacea;* Dr. F. H. Gravely of the Madras Museum and Dr. Gangooli of the Baroda Museum for permitting me to examine the specimens in their charge, and to John Ralahami of Karaduva island for obtaining for me a living female and several skulls of this turtle.

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Reproduction of the Estuarine Crocodile of Ceylon

BY

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(With Two Plates and Eight Text Figures.)

The estuarine crocodile of Ceylon, generally known as *Crocodylus porosus* Schneider [1], does not entirely agree with the commonly accepted characteristics of this species which is usually described as a sea-going form with, or without, vestigial post-occipital scutes. The Ceylon animal is only found at sea when swept down by rivers in heavy flood and displays a tendency to retain post-occipital scutes which are either partially or well developed. The more salient of these are as follows. The dorsal osteoderms are ellipsoid and *always* widely separated from one another by skin; in longitudinal series they are smaller and fewer than the large dorsal scutes and there are none upon the limbs. The snout is longer than one and a half times its basal width and each ectopterygoid extends forward into the anterior quarter of the length of the palatal vacuity. The eggs are buried in a heaped-up mound of dead leaves [2] and this animal does not inhabit inland waters.

Although *Crocodylus porosus* is known from many lands and is generally considered to be the largest living reptile, there is no complete account of its reproduction. The possibility that the heavy demand for reptile skins might develop crocodile farming into a paying concern, makes such knowledge of more than academic interest.

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[1] This species is the genotype for *Oopholis* Gray 1844.

[2] Other long-snouted forms such as *C. johnstoni* Kreft, and *C. cataphractus* Cuvier, which are mound nesters, have some scutes sutured together, as is typical of the genus *Crocodylus*.
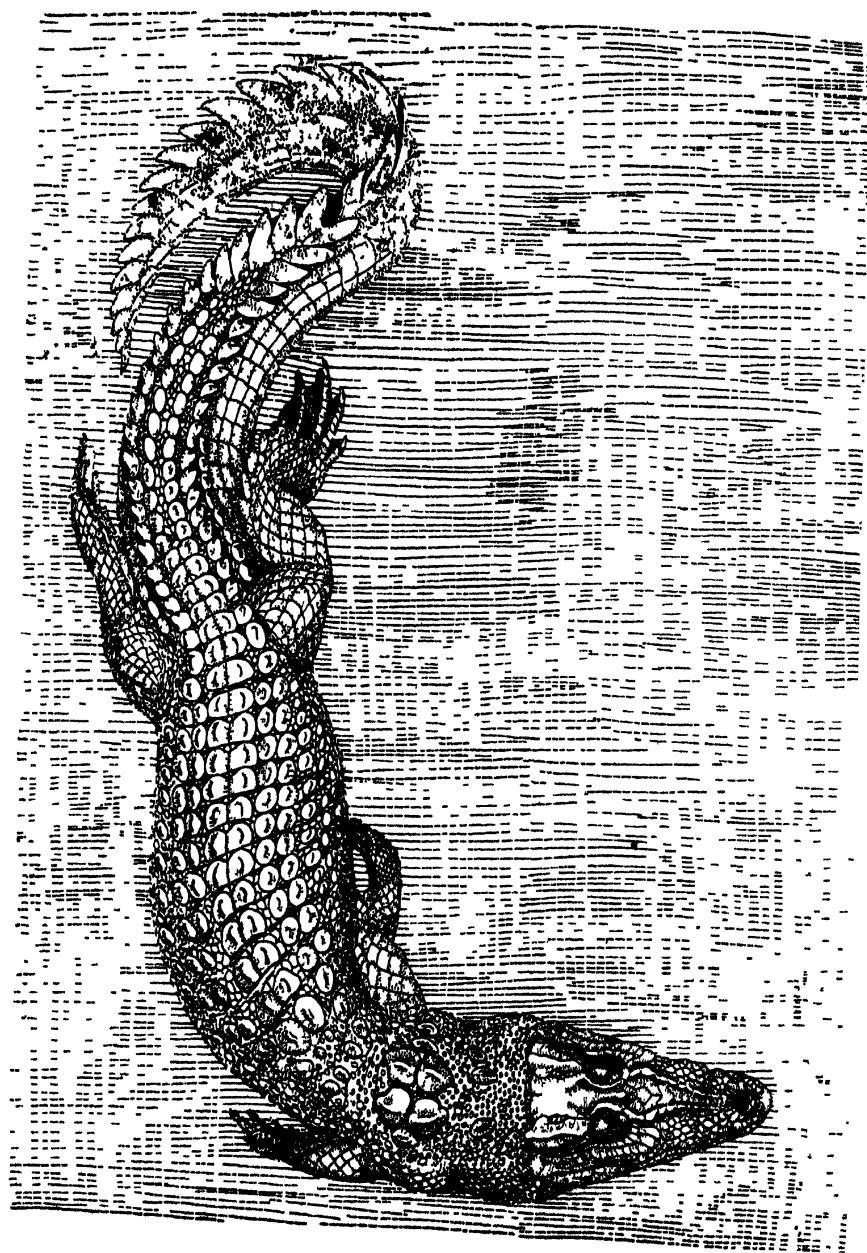
F Deraniyagala del.

Fig. 1 ; Adult *Crocodylus porosus* from Handela × $\frac{1}{13}$

The male is distinguished from the female by its comparatively thicker tail, more intense pigmentation, and more pronounced canthal ridges. It is generally stated that it is only the male that bellows, but this is open to doubt, as all the newly hatched young of a nest, possess voices. During the mating season crocodiles bellow all night and the males are said to fight each other for the females. The heavily scarred snouts of some individuals suggest that these encounters are stubbornly contested and wounds, resulting either from combat or bullets, sometimes fester and render the victim particularly savage. These festering wounds, or their scars, are white, and it is not unusual to hear of the ferocious ' thomba sudha ' white snout, or ' handeya ' moon-forehead, or ' kota ' stump-tail, in places inhabited by this species.

According to the Sinhalese crocodile hunters of Bolgoda (W. P.) and Matara (S. P.), copulation is effected by both animals raising themselves in an embrace in shallow water, the forequarters in the air, with usually the jaws interlocked. After the mating season the female repairs to a secluded Ketela (*Lagenandra toxicaria*) grove and builds a mound-like nest of ketela flags leaves about 60-80 metres from the water's edge where the leaf mould is solid enough to support shrubs and small trees. The nest is known in Sinhalese as ' kola gai '—leaf-house. The men state that the female crocodile annually returns to the same place if undisturbed, but she always builds a new mound.

The nest may be represented diagrammatically by three concentric circles. The outer is the preliminary clearing and is 7-8 m. in diameter. The next which represents the nest mound is 2.5-3.5 m. in diameter, and 0.8-1 m. high. The nest hole near its summit forms the third circle. This is 35-40 cm. in diameter and is under a thickness of about 20 cm. of dead ketela leaves after the eggs are laid. About a metre from the nest the animal digs a trench considerably shorter than its own length, but somewhat wider than its body. This contains mud to a depth of about 80 cm. below water about 5 cm. deep. In this wallow the female remains guarding the eggs from such marauders as the Kaberagoya lizard, *Varanus salvator* (Laurenti), various small carnivores such as mongoose, jackars, otters and man. It is probable that while the female guards her nest she eats but little, if at all, for the stomach of one shot by me was empty. The trench, although small, conceals the animal most effectively and to the inexperienced this guard wallow appears devoid of its tenant (Fig. 2).
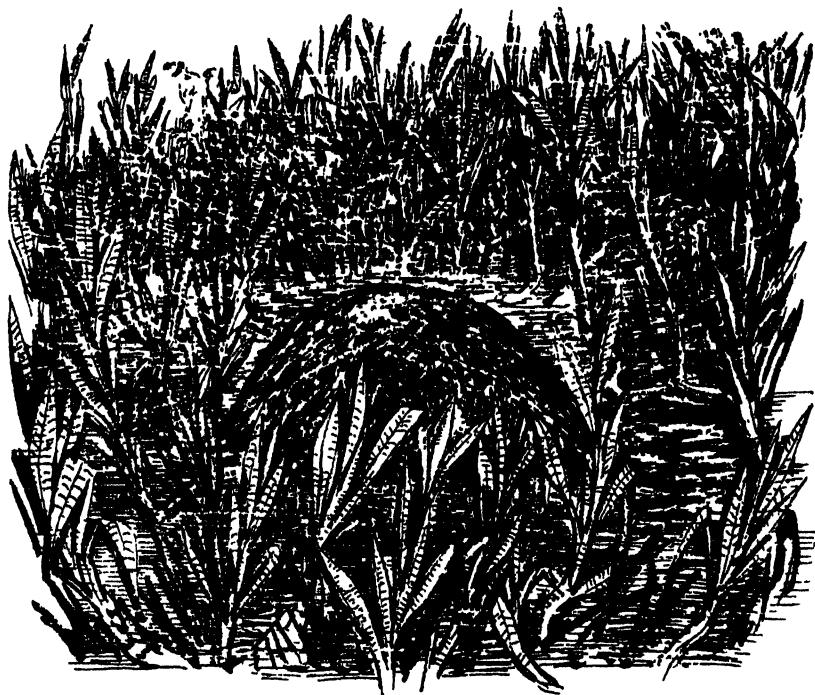
Fig. 2.   Nest (I) of *C. porosus* × $\frac{1}{70}$

Moisture is essential for incubation and the fishermen affirm that the animal sprays the nest from the guard pool by lashing its tail at intervals. Such behaviour is doubtful for neither of two nests examined by me in the height of the dry season showed signs of a muddy spray, which would have been evident had the mother acted in this manner. The spongy ketela stems[1] which compose the nest appear to absorb the requisite moisture from the damp mould on which the nest is built. This material keeps the temperature of the nest comparatively uniform, viz., about 32°C. during the day with a probable decrease of a degree or two during the night. The fresh ketela growth, which rises to the height of about a metre above the nest, appeas to protect it from an excess of the mid-day sun which is particularly powerful at this season. As the eggs occupy the upper third of the nest, they benefit from this modified sunlight, are free from excessive moisture, and less liable to risk from flood than if they lay near the bottom.

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[1] The crocodile hunters of this district assure me that they have never seen fresh ketela leaves in a newly built nest.

Eggs occur from June until September, but the height of the nesting season along the west coast of Ceylon is August. This month is usually one of the hottest, with little or no rain, consequently danger from floods is minimized. The rains, which generally ensue two months later, help to disperse the young which are then carried by the floods and are taken in fish kraals in considerable numbers at this season.

NEST.

The following is a detailed description of two nests from the Bolgoda district, Western Province.

Nest I discovered at Kaputu Dhuva near Maha Bellana (W. P.) on August 13th, 1934. The depth of the river at this place was 5 metres and the salinity of the water rather less than 0.1%. The nest was built near a Kirilla tree *Sonneratia acida*, about 80 metres from the water. The nest clearing was about 7 metres in diameter, that of the mound was about 2.5 m. Its height was about 1 m. and the nest hole near its summit was about 0.5 m. in diameter and contained 40 eggs. These ranged in size from 76 by 50 mm. weighing 105 gm. to 96 by 51 mm. weighing 135 gm. while one abnormal, infertile, egg was only 61 by 44 mm. and weighed 66 gm. These eggs were about 20 cm. beneath the summit of the nest. Around the mound were four depressions caused by the animal digging up the mould, and in one of these was the guard wallow which was 1.5 m. by 2 m. The nest of a weaver bird suspended from a ketela leaf, overhung the nest and the stems of the neighbouring ketela plants were gashed either by the crocodile's teeth or claws. Overgrown with weeds and about 10 metres distant, was an old nest of the previous year probably built by the same animal (Fig. 2 upper right corner).

Nest II discovered on August 18th, 1934, was barely 130 m. from the previous one and in this instance also, a weaver-bird's nest hung over it. The absence of an old nest in the vicinity, and the small size of both the nest and the crocodile guarding it, suggested that this was the first she had built. The distance to water was about 90 m., the nest clearing formed a ring 1.5 m. wide around the mound, which was 1.6 m. in diameter and 80 cm. high with a nest hole 36 cm. in diameter. The nest contained 37 eggs ranging in size from 77 by 50 mm. weighing 115 gm. to 85 by 49 mm. weighing 120 gm. About 1 m. from the nest was the guard pool which was about 2 m. by 1 m. and this my guides prodded with poles for about ten minutes without any response, until I felt certain that it contained no crocodile and

requested them to desist. However they persisted and after about thirty minutes the submerged animal exposed the tip of her snout and emitted growling hisses. When shot, she measured 124 cm. from snout tip to cloaca, the tail, which was mutilated, was 109 cm. The large oviducts testified that the nest was recent, and supported the statement of the men that they first saw the nest twelve days previously when the ketela mould was freshly gathered. The stomach was empty except for gastroliths, which consisted of a few pieces of laterite, and small quartz pebbles probably retained from kaolin clay which is sometimes eaten.
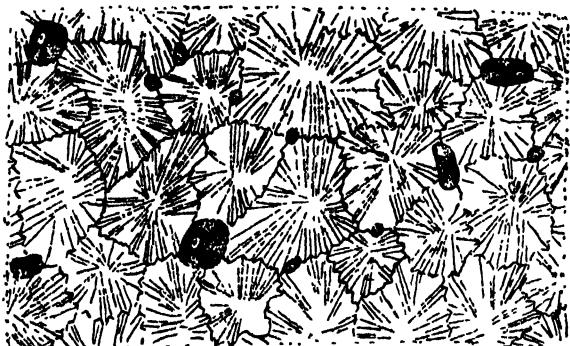
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Fig. 3.   Inner surface of shell fallen off hatching egg × 40

EGGS.

The eggs range from 30 to 50 in number. Those of the same batch vary in length and weight but are comparatively constant in width, while a few abnormal ones are either irregular or small. The egg shell is a mosaic of numerous, minute, sutured platelets [1] which are further cemented together with calcium salts. Their shape and arrangement suggest an epithelial origin. Between the platelets are pores of two sizes of which the larger are further apart than the smaller (Fig. 3). The rugose shell of the newly laid egg at this time adheres closely to the strong membranous layer beneath and shines with an external coat of hardened mucous. The coat apparently absorbs the moisture, necessary for transpiration, which occurs osmotically through both this mucilaginous layer and the membrane

[1] Egg shells of *Testudo elegans* Schoepff and *Geoemyda trijuga thermalis* (Iesson) possess a similar structure.

covering each pore in the shell. It is evident that the developing embryo utilizes much of the calcium salts of the shell causing pieces to flake off readily when the embryo is about to hatch. The salts so utilized are probably replaced by such excretory products as urates and oxalates, for more or less prismatic crystals lie upon the inner surface of each shell platelet of the fallen shell fragments (Fig. 3). Thus the shell finally becomes so friable as to be no obstacle to the young when hatching.

As incubation progresses the pores enlarge, the shining, exterior disappears, and the shell becomes stained with the surrounding mould. It is also noticeable that the white chalky band which commences around the short axis of the membraneous cover spreads over most of this protection by the time the embryo is ready to hatch. The membrane itself consists of two fibrous layers, an external one with fibres running obliquely to the long axis of the egg, and an inner layer of spiral fibres. The albumen is a pale yellowish green and so viscid in the new laid egg, that it is possible to separate the pale yellow yolk which is of the colour of clouded amber, by pulling or cutting away the surrounding albumen. There are no chalazae.

The period of incubation ascertained from two batches of eggs hatched in the laboratory was 96 days, but it is probable under natural conditions it rarely exceeds two and a half months.

TABLE I *Individual egg weights and dimensions.*

Weight in gm.	Dimension in mm.		
	Nest I 32 eggs	Nest II 20 eggs	Nest III 10 eggs
66	61 × 44	—	—
90	—	—	70 × 45
	—	— .	76 × 44
92	—	—	74 × 45
93	—	—	70 × 46
94	—	—	72 × 46
	—	—	73 × 45
	—	—	74 × 46
	—	—	85 × 42
96	—	— .	76 × 45
98	—	—	71 × 47
105	76 × 50	80 × 50	—
115	—	77 × 50	—
116	—	75 × 51	—
	. —	76 × 51	—
	—	78 × 50	—
119	—	77 × 51	—
120	79 × 51	75 × 50	—
	81 × 51	78 × 50	—
	82 × 51 (two)	77 × 51	—

Weight in gm.	Nest I 32 eggs	Nest II 20 eggs	Nest III 10 eggs
	—	78 × 51	—
	—	80 × 49	
	—	85 × 49	
	—	76 × 51 (two)	
122	80 × 51	82 × 50	—
123	—	77 × 51	—
124	85 × 51	83 × 50	—
	87 × 51	—	—
	83 × 51 (three)	—	—
125	83 × 51 .	80 × 51	—
	84 × 50	—	—
	84 × 51	—	—
	85 × 51	—	—
	90 × 49	—	—
	82 × 51 (two)	—	—
128	84 × 51	—	—
	86 × 51	—	—
	82 × 51 (two)	—	—
129	81 × 52	—	—
130	85 × 52	86 × 49	—
	89 × 51	—	—
	87 × 51 (two)	—	—
131	85 × 51	—	—
133	89 × 51	—	—
134	85 × 51	—	—
135	96 × 51	—	—
140	—	92 × 49	—

Dimensions in mm.

TABLE II   *Average egg weights and dimensions.*

Nest.	Eggs measured	Length	Breadth	Weight
I	32	83.75 mm.	50.69 mm.	123.8 gm.
II	20	79.4 ,,	50.25 ,,	120.5 ,,
III	10	74.1 ,,	45.1 ,,	93.5 ,,

EMBRYOS

Embryos were studied from the two nests described and with the exception of stage A, displayed family characters. Consequently they might be regarded as *late* [1] embryos. The stages here described were obtained from nest II found at Bolgoda on August 18th, 1934. From information given by my guides, this nest was first discovered by them twelve days previously, when it appeared freshly built. Hence it is decided to accept the 5th of August as the date of laying, thereby giving the first embryos of the series, which were extracted on August 20th an age of sixteen days. Nest I when first discovered on August 13th, 1934, had advanced embryos which were fully pigmented and only the last phases of development and hatching could be studied from these.

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[1] *Narly* embryos are those which do not display such characters.

The eggs were surrounded with ketela mould from their nests and deposited in metal buckets kept in the laboratory. They were sprinkled with water once every other day, and so placed that sunlight fell upon the buckets between 2.30 and 4 P.M. They were examined from time to time, consequently the temperature in the mould during the day varied from 27° -30° C. The eggs of nest I commenced to hatch on September 5th, the last hatched on September 13th. The eggs of nest II were utilized for their embryos with the exception of four. These four retained hatched on November 9th, 1934, i.e., after a period of ninety-seven days incubation, but were distended with yolk and abnormal. They were killed soon after they hatched. The interval of eight days between the hatching of the first and last eggs of nest I, together with the distended young of nest II, as already stated, suggests that incubation was by no means normal. It is probable that under natural conditions the eggs hatch in two and a half months.
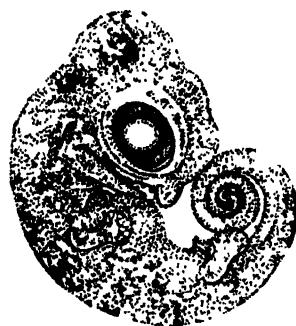
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Fig. 4.   Sixteen day old embryo of *C. porosus* × 2.3

Stage A. The smallest of the series were embryos from nest II extracted on August 20th and estimated to be sixteen days old (Fig. 4). Their dimensions were as follows:—curved length 17-19 mm.; head, length 11-12 mm.; depth 9-11 mm.; length of eye opening 5-6 mm.; gape 5.5-6 mm.; axilla to groin 7-8 mm.; straightened tail 17.20 mm. The embryo was unpigmented. The head which was larger than the body was flexed on to the cardiac protuberance,

while the tightly coiled, elongate tail touched the fore brain. The nostril was lateral and the protruding eyeballs were pigmented and possessed the rudiment of a nictitating membrane beneath an annular eyelid. The rudiment of an ear opercle was also present. The upper jaw was considerably longer than the lower. The most extraordinary feature in this early stage was the presence of large, fleshy, tooth rudiments which were wide apart and projected from the jaw. They occupied the anterior part of both jaws. On each side there were three premaxillary ' teeth ' and three larger ones along each maxillary, while on the mandibulars there were only two. The ectodermal branchial grooves had disappeared but there were two throat folds. The limbs terminated in discs in which the digits were discernable. The anterior limbs displayed the elbow joint and a feeble lateral fold extended from above the limbs to the tail, which was thick and had an obtuse, kinked tip.

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Fig. 5.   Twenty-six day old embryo *C. porosus* × 1.4

Stage B. These embryos were obtained on August 30th and hence were twenty-six days old (Fig. 5). Their dimensions were as follows:—curved length 28 mm.; head, length 17 mm.; depth 14 mm.; length of gape 12 mm.; axilla to groin 11 mm.; straightened tail 29 mm. The most conspicuous feature at this stage was the egg yolk which had formed a cup to contain the embryo. This cup

consisted of several ill-defined lobes while its lip was broken into lobules. The embryo was unpigmented and lay on its left side with the tail curled under its right hind leg and over the right flank. The head was still flexed on to the cardiac protuberance, which was smaller than in stage A. The nostrils were dorsal, and a lateral ridge, the canthus rostralis, extended along each side of the snout and appeared to be confluent with the upper part of the eyelid, which was still annular. The ear opercle was more advanced than in A, extended anteriorly to the eye and was feebly emarginate in the middle. The upper jaw was still longer than the lower, but displayed the pre-maxillo-maxillary constriction and possessed, at its tip, a bifid egg tooth with the points wide apart. The tooth rudiments had increased in number, but were not as long proportionately as in A. A lateral fold extended from the ear down the neck to the shoulder. The limbs were altering their shape and the wrist and ankle joints were recognizable, while the digits of the hand had begun to project from the terminal disc. The foot had made further progress towards its final shape than the hand, and had elongated. The tail was stout, but the caudal crest was not yet apparent. The caudal kink was noticeable and in the living animal was well supplied with blood [1]. The genital prominence was well developed and extruded. Lepidosis had commenced and the dorsal scales, formed band-like transverse series. The embryo was now definitely of loricate shape as denoted by the premaxillo-maxillary constriction of the upper jaw, the more dorsal nostrils, the ear opercle and its relative position to the eye, the bulky tail and lepidosis.

Stage C was obtained on September 11th, and was thirty-seven days old. Its dimensions were as follows:—straightened length 81 mm.: head, length 21 mm.; depth 16 mm.; length of gape 14 mm.; snout, length 5 mm.; width 5 mm.; axilla to groin 14 mm.; straightened tail 33 mm. This was the last unpigmented stage. The eyes were still prominent and the nictitating membrane covered about one-fifth of each. The edges of the jaws had begun to assume the characteristic wavy outlines of the family and possessed numerous low protuberances, vestigial ' gums '. The digits had differentiated and those of the fore limb were separate from each other. The caudal crest had also begun to be noticeable. The head and limbs were scaleless and the genital prominence conspicuous.

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1 The extinct suborder Thalattosuchia of upper Jurassic strata of Europe, possessed a terminal caudal fin which probably originated by hypertrophy of a similar structure (see Text Fig. 6). Should this view prove correct, the skeleton of the caudal fin must have been in the dorsal lobe not the ventral as figured by Williston. The ventral position in the fossil is probably due to collapse of the lobe due to putrefaction.

The embryo was now recognizable as a crocodilian by the shape of its jaws, the number of digits and caudal crest.

Stage D. This embryo was obtained on September 19th, and was forty-five days old. Its dimensions were as follows:—curved length 46 mm.; head and body 55 mm.; straightened tail 41 mm.; head, length 25 mm.; depth 17 mm.; length of gape 17 mm.; snout length 8 mm.; width 6 mm.; axilla to groin 18 mm.; depth of body 12 mm. Yolk sac 78 × 42 × 36 mm.

The pigmented embryo lay on its left side in the cupshaped, lobulate yolk. The tail was coiled between the hind legs. The points of the egg tooth were now closer together. The eyes were less prominent and the nictitating membrane covered half the eye. The head was scaleless but covered with sense organs. The genital prominence was as in the previous stage, but bifid at the tip. Lepidosis was more or less complete and the scales formed 60 transverse rows from the first dorsal row to tail tip. The latter was still kinked and there was fusion of the scales posterior to the thirty-fifth ring of caudal scales, while in some individuals fusion had commenced behind the thirty-ninth ring. It was also noticed that in some embryos the penultimate hook was smaller and located more antero-dorsally than shown in Fig. 6. The hook itself appears to result from the fusion of the fortieth to the forty-third ring of caudal scales.
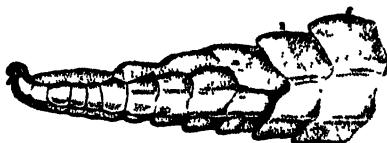
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Fig. 6. Penultimate caudal hook in embryo *C. porosus* × 8

Pigmentation was as follows:—There was a diffuse dark band on each side of the snout and a diffuse spot on the posterior half of the ear opercle. A dark spot was also present on each of the external and posterior nuchal scales. Several of the outer dorsal scutes were dark, forming five short, irregular transverse rows of spots which did

not reach the mid-dorsal line. There were eight dark caudal cross bars which were most distinct dorsally and disappeared ventrally. The limbs were not noticeably pigmented.

Stage **E.** This specimen obtained on September 22nd was forty-eight days old (Fig. 7). The white zone had almost completely invested the membraneous cover of the egg leaving only two small areas at each end. The dimensions of the embryo were as follows:— Total length 119 mm.; head, length 29 mm.; depth 17 mm.; length of gape 18 mm.; snout length 10 mm.; width 8 mm.; axilla to groin 23 mm.; length of tail 50 mm.; depth of body 16 mm.; weight of embryo 9 gm.; egg 79 × 50 mm.; weight of egg 117 gm.; size of yolk sac 80 × 60 × 25 mm.
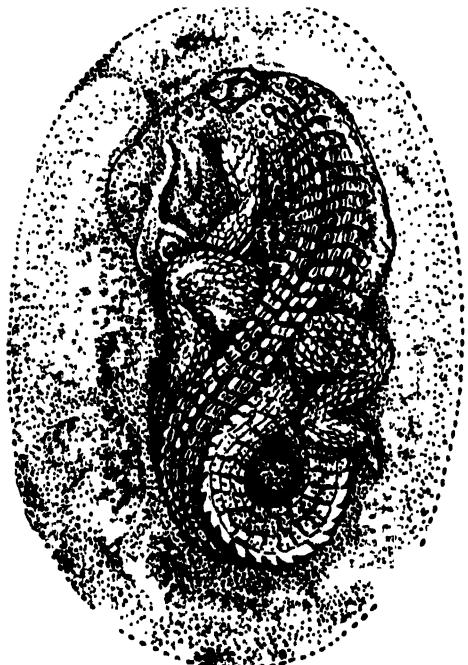
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Fig. 7. Forty-eight day old embryo of *C. porosus* × 1

The animal now lay prone and twisted into a figure 8. Each hand and forearm was overlapped by the corresponding foot. The snout was under the left arm, the tail was twisted to the right and tucked beneath the right foot. The umbilical blood vessels passed out to the left and ramified over the four lobes of the yolk to the left of the animal. The nictitating membrane covered half the eye, and the pupil which was hitherto rounded, was now vertically elliptical. The claws were noticeably elongate and underneath each was a jellylike pad, the entire structure forming a neonychium. The genital prominence was less lobulate than before. The upper jaw was wider and still slightly longer than the lower, but the canthus rostralis was less prominent than hitherto. The halves of the lower jaw appeared incompletely united at the symphysis. A series of pits separated the row of ' gums ' from the palate. In the adult only two of these pits persist anteriorly, and these receive the first pair of mandibular teeth [1]. The head now showed incipient lepidosis upon the premaxillary region. The body lepidosis displayed a feature of considerable interest, for a series of small scales [2] entirely separated the two contiguous, median, longitudinal dorsal rows from the next lateral rows. Most of these intervening small scales appear to be pressed out later by the development of the others, for at birth usually all the large scales are contiguous except in the four anterior rows. These small scales were rhomboid or triangular whereas the large ones are nearly elliptical. Between the ninth and nineteenth transverse rows of dorsals each intervening small scale possessed a small black dot. These in a double series of spots along the back. There were sixty transverse rows of scales from the first dorsal series to the tip of the tail. seventeen of these were dorsal and the caudal crest became uniserial after the thirty-seventh transverse row. The ventral scales were prominent and ranged into about twenty-four or twenty-five conspicuous transverse bands from axilla to groin. The embryo was pigmented as follows:—there was a diffuse dark lateral band on the snout and a similar patch over the posterior half of the ear opercle, while, whenever post occipital scutes were present, each was bordered by a small spot. Spots were also faintly visible upon the neck, while the outer nuchal scutes were dark. There was a diffuse shoulder blotch on each side. Five irregular, short, oblique dark bands, which fail to reach the mid-dorsal line, marked the carapace. Each band consisted of one or two dorsal scutes. Below these on each flank were three longitudinal rows each consisting

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[1] In alligators another pair of pits also persists to receive the fourth pair of mandibular teeth.

[2] Vestiges of these scales persist anteriorly in many adults (Fig. 1).

of ten smaller spots. The limbs were feebly spotted. The tail had ten or eleven dark irregular dorsal bars which were continued ventrally in its posterior half. A row of fine dots ran between the vertebral row of dorsal scales and the next large longitudinal row on each side. The belly was immaculate.

The majority of specific characters were now present, but a cnemial fringe on the limbs was but feebly developed. The dorsal scutes still continued in well defined transverse rows. Both these features are characteristic of the adult of the genus *Osteoblepharon* Schmidt.

Stage **F.** A sixty day embryo from nest II was killed on October 3rd. As it was only at a slightly enlier stage than one from the nest I killed on August 13th, they are both dealt with together. The dimensions of the former were as follows:—(a) Total length 170 mm.; head, length 34 mm.; length of gape 22 mm.; axilla to groin 32 mm.; head and body 86 mm.; weight of embryo 20 gm.; size of egg 76 × 51 mm.; weight of egg 120 gm. The embryo was 2.2 times as long as the egg and one-sixth of its weight. (b) The dimensions of the latter were as follows:—Total length 200 mm.; head, length 38 mm.; depth 20 mm.; length of gape 25 mm.; head and body 99 mm. The genital prominence was completely withdrawn. The egg displayed only one dark terminal patch, while the remainder was entirely occupied by the white calcareous zone in the membraneous cover. An incision made at this patch exposed a residual mass of greenish yellow albumen. The snout of the embryo was close to the opposite end of the egg and on the other side of the yolk. The tail was curled over the right thigh. Four blood vessels radiated from the umbilicus; each pair entered a solid, transparent, jelly-like mass, about the size of the animal's head minus the snout, and ramified over the allantois, which now completely invested the inner surface of the egg cover. The eyes were no longer protuberant. The snout scales were complete, while the dorsal scales lay in six more or less contiguous longitudinal rows, although vestiges of the small dotted scales persisted in the region of the hips. Sense organs were distributed as follows:—The scales upon the nasal bump and along the sides of both jaws carried several. The median row of enlarged snout scales, were probably of a composite nature, for their halves were unequal, and there was a sense organ on the lateral end of each. The posterior end of the ridge on each postoccipital, nuchal and dorsal scale, was furnished with a sense organ. All ventral scales except two or three along the sides of the

umbilical scar had only one sense organ on each, the latter possessed two. The palate was covered with large glandular scales, each with one or two sensory papillae. There was a yellow patch posteriorly on the palate which gave out a fibrous median streak which extended anteriorly and bifurcated. Each branch ended near the last premaxillary tooth. A fleshy papilla existed between the two pits which receive the first two mandibular teeth. The other pits in the anterior part of the jaws were much constricted. The teeth were visible through the gums but had not ' cut ' through. In the lower jaw the tongue was well demarcated from the throat skin which was thrown into numerous transverse folds and occupied the anterior half of the floor of the mouth. The tongue had its taste organs clearly defined and there was a translucent, pinkish elliptical patch in its centre. The genital prominence which had begun to disappear in (a) was completely withdrawn in (b). Each claw possessed a neonychial pad.

Pigmentation was much advanced. The vertex was purplish, and the double row of dorsal black dots was now restricted to the hip region. There were two blotches at the base of the lower eyelid and three minute spots under the eye. There was a row of seven small spots from jaw to shoulder and four longitudinal rows of ten in each from axilla to groin. There were eleven caudal transverse black bands. At this stage the extracted embryo snapped its jaws and objects placed in the mouth were seized and jerked viciously from side to side with swinging, lateral movements of the head.

Stage **Q.** Two embryos of nest II were killed on November 9th and did not differ greatly, in dimensions, from embryos of nest I killed on September 5th. Their dimensions were as follows :—Straightened lengths 295 and 285 mm.; head, length 49 and 46 mm.; snout, length 21 mm.; width 16 mm.; gape 34 mm.; axilla to groin 55 mm.; snout to cloaca 146 and 143 mm. (Fig. 8).

The embryos were now 96 days old and ready to hatch. The yolk sac was no longer visible. At this stage the animal would be in a sitting position if the egg were erected upon its long axis. The head was flexed on to the chest. The snout, which was inclined to the left, was still covered by the left hand while the latter was covered by the foot. The position of the tail had altered and now curled over the right shoulder and downward towards the left leg, while its right side touched the egg shell. The last eleven elongated scales of its crest were twisted round the left thigh so that the left side of the tail touched the egg shell. Pigmentation was complete.
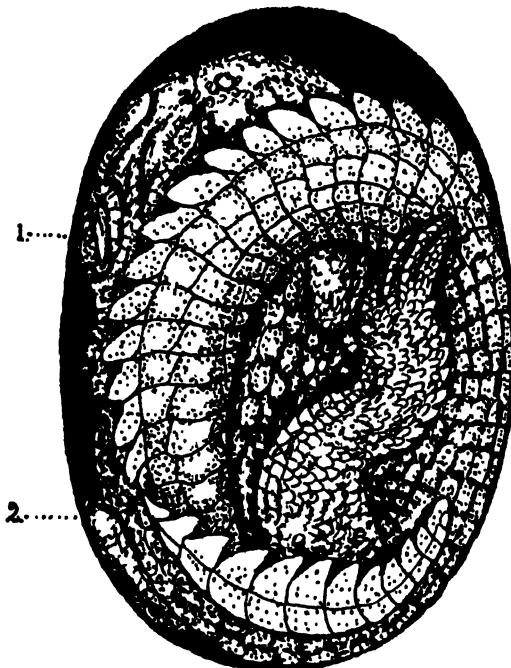
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Fig. 8. Ninety-six day old embryo of *C. porosus* ready to hatch × 1

1 = eye; 2 = left thigh

HATCHING

Stage **H.** The process of hatching was observed in several instances. Two specimens hatched as follows (Plate XXX):—

1. A crack appeared on the side of the egg shell at 8.20 A.M. and the baby was heard to croak within the unperforated case. At 8.35 A.M. a terminal crack appeared at one end of the egg and ten minutes later the two united. At 8.50 A.M. the snout emerged from the terminal crack, with the lower jaw to the left and the upper to the right of the long axis of the egg (Plate XXX, Fig. 1). There were four pieces of shell against the lower jaw and one against the upper, and two cracks ran longitudinally down the egg, but did not

involve the membraneous case. At 9 A.M. the animal emitted two very feeble yelping croaks which sounded like ' gnuc ' and at 9.15 A.M. gave two more which were louder. At 10 A.M. the animal croaked three times and twisted so that the lower jaw was uppermost and probably continued to alter its position within the egg or in ten minutes albumen began to ooze in spurts from the opening (Plate XXX, Fig. 2). At 10.35 A.M. the snout rotated to the left and was projected until its base appeared, while a blood vessel of the rent amnion lay across it. The egg case was next torn downward to the right, the snout enlarging the rent which was now as long as the head. At 10.40 A.M. the animal moved its snout to the right and projected it as far as the eyes, which remained closed. After remaining like this for two seconds it withdrew the eyes into the egg shell. At 11 A.M. the animal sprang out of the shell with a jerk, evidently propelling itself by suddenly straightening out the flexed tail. The umbilical stalk continued to connect it to the egg case. The crocodile now moved its ear opercles, opening and closing them in quick succession for several seconds (Plate XXX, Fig. 3).

2. Another egg was found chipped at 8 A.M. but no sound was audible from the animal within until after the premaxillary tip of the snout had emerged from one end of the egg at 8.15 A.M. At 9 A.M. it burst out of the shell without any further struggling and as it did so the crackling of the shell was distinctly audible. As before the umbilical stalk still connected the crocodile with its recent shelter, and continued to do so for several hours.

The first indication of hatching probably occurs as the head is shifted from its flexed position (Fig. 8). This action chips a small piece of shell exposing about 2 × 4 mm. of the membraneous case located a little to one side of the short axis of the egg (Plate XXX, Fig. 1). The terminal fracture, from which the animal finally emerges, occurs a few minutes later and the egg now oscillates if placed on a flat surface. A new longitudinal crack now connects the first two fractures, about ten minutes later two or three further longitudinal cracks appear. About half an hour after the first indication of hatching, the snout pierces the exposed membrane at the fractured end of the egg, causing pieces of the shell to dehisce and generally to fall off along the existing cracks. When the snout is first protruded, usually there are three or four small pieces of shell against the lower jaw and one against the upper. At first, only the premaxillary portion of the snout is exposed, and the animal occasionally emits a yelping croak. The snout is next withdrawn, and judging from the albumen

which issues in spurts from the shell, the animal evidently adjusts its position. It then thrusts out its snout for a second time, and after an interval projects its head as far as the eyes. It remains in this position for a few seconds, then bursts out of the shell.

Some interesting features were noted with regard to the process of hatching. The egg when immersed in water would neither float nor bob about like a bird's egg, but sank to the bottom and occasionally oscillated. These vibrations were readily felt when the egg was held in the hand. It now weighed considerably less than when newly laid, for an egg from nest III which was 90 gm. on October 3rd, was only 87 gm. on October 18th, immediately previous to hatching. The newly hatched young were about 0.71 times the weight of the newly laid egg, and about 3.6 times as long.

The fluid that issued out of the egg possessed a strong smell of urine as did the newly hatched animal which was smeared with it. This appeared to result from the escape of excretory products hitherto stored up in the allantois. The newly hatched crocodiles were very responsive to each others croaks, and specimens isolated in a tub at once began to croak on hearing another they could not see, at the other end of the room. When all were placed together they were silent. It is probably this responsiveness that causes ten or fifteen young to appear together of a morning in the same fish kraal. The young employed their teeth but not their tails which were slightly prehensile [1]. Directly they hatched they were very savage, croaking and springing at an intruder with their fore limbs off the ground in an attempt to bite, dragging the egg shell to which each was still connected as they did so. However, soon after they were sprinkled with water they become relatively quieter and more retiring. At birth the abdomen contained yolk material which was not absorbed for about two days. After this interval defaecation commenced and tinged the water a bright transparent yellow.

When first placed in water the animal spread wide all four limbs and scrambled like a puppy, each limb working independently of the others. Within a few seconds however it learnt to keep the fore limbs close to its sides and swam by undulating movements of its body and tail. The buoyant yolk material in its abdomen afforded little impediment to submerging and the animal in commencing to do so, first sank backwards and then went forwards as does the adult.

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[1] A characteristic rather common among newly hatched Squamata, even among such fragile tailed forms as geckoes, e.g., genus *Hemidactylus*.

The first pair of mandibular teeth had not perforated the upper jaw and the animal retained its egg tooth for about ten days after birth. At this stage there were no osteodermal platelets.

TABLE III. *Weights (gm.) and dimensions (mm.) of developing eggs and embryos.*

Serial number	Tail length	Head length	Length of young / Length of egg	Egg length	Length of young	Weight of egg / Weight of embryo	Weight of embryo	Egg Weight	Days before hatching	Egg width
					Nest	**I.**				
1	120	41	—	—	225	—	—	—	25	—
2	115	40	—	—	223	—	—	—	25	—
3	116	39	—	—	220	—	—··	—	25	—
4	116	40	—	—	223	—	—	—	25	—
5	106	38	—	—	200	—	--	—	25	—
6	125	42	—	85	260	—	46	131	19	51
7	132	42	—	85	260	—	48	134	19	51
8	170	50	3.69	84	310	1.33	96	128	0	51
9	162	49	3.58	85	305	1.35	96	130	0	51
10	168	48	3.69	84	310	1.38	90	125	0	51
11	151	51	3.02	96	290	1.58	85	135	0	51
12	158	49	3 68	80	295	1.35	90	122	0	51
13	143	46	3.43	83	285	1.31	95	125	0	51
14	162	49	3.69	83	307	1.37	90	124	0	51
15	150	48	3.32	89	296	1.44	90	130	0	51
16	168	50	3.56	87	310	1.44	90	130	0	51
17	145	49	3.81	76	290	1.40	75	105	0	50
18	172	47	3.87	81	314	1.35	95	129	0	52
					Nest	**II.**				
19	29	17	—	77	65	—	—	115	71	50
20	33	21	—	78	81	—	—	116	60	50
21	—	25	—	76	96	—	—	115	51	50
22	59	29	—	79	119	—	9	117	49	50
23	67	30	—	78	127	—	10	120	43	51
24	84	34	—	76	I70	—	20	120	37	51
25	110	39	—	83	222	—	32	124	27	50
26	140	44	—	82	272	—	54	122	16	50
27	165	46	3.26	92	300	1.75	80	140	0	49
28	160	46	3.62	80	290	1.31	80	105	0	50
29	157	46	3.81	76	290	—	70	—	0	50
30	160	46	3.68	80	295	—	85	—	0	50
					Nest	**III.**				
31	80	32	—	71	160	—	17	98	37	47
32	90	36	—	76	182	—	21	90	37	44
33	117	34	—	70	175	—	20	93	37	46
34	130	42	—	70	242	—	46	90	32	45
35	153	45	4	70	280	1.28	70	90	0	45
36	157	47	3.91	74	290	1.34	70	94	0	45

TABLE IV   *Weight and length ratios of egg and just hatched young.*

	Nest I (11 young)	Nest II (2 young)	Next III (2 young)
Weight : $\dfrac{\text{egg}}{\text{young}}$	1.39	1.53	1 31

Average total ratio (15 young from 3 nests) $= \dfrac{20.98}{15} = 1\ 39$

	Nest I (11 young)	Nest II (4 young)	Nest III (2 young)
Length : $\dfrac{\text{young}}{\text{egg}}$	3.57	3.59	3.95

Average total ratio (17 young from 3 nests) $= 61.62$

$$\frac{}{17} = 3.62$$

ABNORMALITIES.

Only a single abnormal embryo was noted from the several broods of various ages. This specimen, which was otherwise normal, possessed eight toes on each posterior limb and was 78 mm. long. The tail which was 75 mm. retained the caudal kink. Lepidosis was nearly complete and pigmentation had commenced.

OSSIFICATION

Ossification was studied in embryos of stage B and older specimens by staining the bones red with alizarin and clearing in glycerine. Plate XXXI depicts one of the younger stages thus examined. The dimensions of the embryo were as follows: Length of head 16 mm., length of gape 10 mm., length of eye 6.5 mm., depth of head 11 mm., axilla to groin 10 mm., length of tail 25 mm.

All the skull bones were separate and several had not yet begun to ossify. The jaw bones contained tooth rudiments and there were three or four fleshy tooth like projections along the edge of the jaw which showed no signs of ossification.

The ossification of this embryo was as follows: The premaxillary (1) was nearly as long as the maxillary (2) which was forked anteriorly. Both bones possessed tooth rudiments. The outer process of the maxillary was spike-like, the inner flattened and curved upwards. The nasals (3) were wider than the maxillaries and at an earlier stage were as long. The premaxillaries, maxillaries, and nasals bordered the narial aperture. The lacrymal (4) consisted of two curved parts narrowly connected. It is possible that in earlier stages these are separate. The prefrontal (5) was deep set and smaller than the

lacrymal. The frontals (6) were separate, large, and showed marginal ossification which was most intense along the upper edge of the orbit. The postorbital (7) was small and rather deep seated, and extended under the anterior end of the ear slit. Above this slit lay a spatulate bone, the squamosal (9). At the back of the head, between and above the posterior ends of the squamosals, lay the interparietal (8). The two parietals and the supraoccipital which later surround this were still unossified. The former ossify well in advance of the latter and like the frontals do not fuse together until the embryo has completed lepidosis and pigmentation [1]. Beneath the posterior corner of the ear slit and at right angles to it was a deep seated, diffuse ossification, the cartilaginous quadrate bone (10). Obliquely tilted over the angle of gape was the quadratojugal (11), and underneath the eye was a broad bone forked anteriorly, the jugal (12).

The bones of the lower jaw consisted of a subquadrangular articular (13) forked anteriorly, in front of which was the smaller surangular (14), also forked anteriorly. Below the articular was a long splint like bone running along the lower edge of the jaw. This was the angular (15), and beneath it was a diffuse ossification, the cornu of the hyoid apparatus (16). At the tip of the lower jaw was a short bone with two teeth, the dentary (17) while the splenial (18) was nearly three times as large and strongly forked posteriorly.

The interclavicle (19), the scapula (20), the humerus (21), ulna, radius and five metacarpal bones were ossified. The upper parts of ten dorsal ribs (22) were also ossified. On each side of the abdomen were seven abdominal ribs or gastralia (23), anterior to a forked pubic bone, which possessed two or three prongs (25), and below was a vestigial eighth abdominal rib or prepubis (24). It is also of interest to note that the fifth abdominal ribs are generally small. The bones of the hind limb were as developed as in the fore limb but there were no signs of ossification in the tail. No trace of osteoderms appear until several months after hatching.

SUMMARY.

Stage A. Sixteen days old, tail length 17-20 mm. Unpigmented. Upper jaw longer than lower. Fleshy tooth rudiments on both jaws, nostrils lateral, limbs with terminal discs. Elbow joint and digits recognizable. Caudal kink present (Fig. 4).

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[1] Postnatal growth results in relative increase in length of snout and in size of the supra-temporal vacuities.

Stage **B.** Twenty-six days old, tail length 29 mm. Embryo in a cup formed by the yolk. Nostrils dorsal. Premaxillo-maxillary constriction visible. A bifid egg tooth present. Limb joints visible. Lepidosis commenced. Embryo of loricate shape. Relative proportions of skull bones resemble extinct forms. Caudal kink present (Fig. 5).

Stage **C.** Thirty-seven days old, tail length 33 mm. Last unpigmented stage. Edges of jaws wavy and with vestigial gums. Digits differentiated. Caudal crest visible, scales of caudal kink fusing. Embryo definitely crocodilian.

Stage **D.** Forty-five days old, tail length 41 mm. Embryo pigmented. Head covered with sense organs but scaleless. Genital prominence with a feebly bifid tip.

Stage **E.** Forty-eight days old. Length of tail 50 mm. Embryo twisted into a figure 8 on yolk. A series of pits between ' gums ' and palate, Cephalic lepidosis begun. The rows of large dorsal scales separated by rows of smaller ones. Many specific characters present (Fig. 7).

Stage **F.** Sixty days old. Length of tail 84-111 mm. Egg membrane almost completely occupied by the white calcareous zone. Intervening small scales between large dorsal rows disappearing. Sense organs prominent upon scales. Pits on jaws constricted, teeth visible under gums. Last appearance of genital prominence.

Stage **G.** Ninety-six days old. Length of tail 143-158 mm. Egg shell easily flakes off the membranes cover. Embryo ready to hatch and occupied a sitting posture in the egg if erected on its long axis (Fig. 5).

Stage **H.** Hatching. Some animals croak from within the imperforate egg, others are silent. Egg sinks in water and oscillates. Egg tooth of but little service, for animal merely bursts through membraneous case where the shell has flaked off. Exit from shell effected by sudden straightening of tail. Animal smells strongly of urine. Umbilicus connects creature to egg shell for some time after hatching. Egg tooth retained for about ten days. Anterior mandibular teeth have not yet perforated through the upper jaw. No osteoderms. Young about 3.6 times as long as egg which is about 1.4 times as heavy as the newly hatched animal (Plate XXX).

CONCLUSIONS

The reproduction of *Crocodylus porosus* discloses embryonic phases of considerable taxonomic importance and in some instances these

suggest evolutionary changes similar to those ascribed to the order Testudinata [1]. The more interesting features in this paper are as follows : —

(1) The egg shell consists of numerous calcareous platelets, sutured and cemented together. Between them lie pores of two sizes. The platelets are possibly of epithelial derivation (Fig. 3).

(2) The early embryonic appearance of the bifid egg tooth and its late postnatal persistence are remarkable. It is doubtful whether so strong a structure is solely maintained to perforate a membraneous egg case from which the shell has flaked off.

(3) The caudal kink is better developed, and more persistent in embryonic Testudinata [1] and Loricata than in Squamata. Hypertrophied, it might have supported the terminal fin of the extinct Thalattosuchia (Figs. 5 and 6).

(4) The embryonic dorsal scutes primarily form more conspicuous rows transversely than longitudinally. There are reasons for supposing that ancestral testudinates were similarly protected [2]. Such an arrangement is apparently primitive (Figs. 5 and 7).

(5) The lateral position of the nostrils and their subsequent dorsal migration, supports the view that crocodiles were once essentially terrestrial and subsequently became aquatic.

(6) The suppression of some longitudinal rows of dorsal scales in the mature embryo suggests that, in a former terrestrial environment, the scutes enlarged to afford better protection and consequently underwent numerical reduction as in the testudinates [2]. It is probable that more specialized forms possess fewer longitudinal rows of scutes [3] than less specialized ones.   '

(7) Towards the commencement of ossification, the relative proportions of several skull bones resemble those in extinct forms and are as follows : the forked phase of the maxillaries, the wide nasals, the paired frontals and parietals, which do not fuse until late in embryonic life, the conspicuous and superficial interparietal and the elongate splenials. The forked maxillaries possibly denote some connexion with the anteorbital vacuity of extinct forms, while the wide nasals and paired frontals and parietals are evidence of relationship with the extinct Phytosauria (Plate XXX).

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[1] Deraniyagala, P. E. P. 1932—Notes on the development of the Leathery Turtle. *Ceylon J. Sci.*, (B) XVII, p. 61.

[2] Deraniyagala, P. E. P. 1934—Corselet reduction in some Testudinates. *Ceylon J. Sci.* (B) XVIII.

[3] Extinct forms with fewer and larger scutes, sutured together possibly retained them better after death, than did species with smaller and more numerous ones. The scutes of the former were less easily scattered and more liable to be fossilised under such circumstances.

(8) The numerical reduction of the anterior tooth pits in the upper jaw suggests that the more specialized species possess fewer pits than less specialized ones.

(9) The change of shape of the supra-temporal vacuities is of importance. In mature embryos and young, each vacuity is relatively small but opens into a superficial slit-like groove between the parietal and, squamosal bones. As the animal develops, the vacuities enlarge their relative size and become comparatively circular. It is suggested that these openings are proportionately larger in more specialized forms. In the living representative of such an old branch as the Gharials, and in several extinct forms, these vacuities are so enlarged as to be of phylogerontic significance.

(10) It is suggested that the progress of specialization among species of living crocodiles can be estimated by studying the extent to which the adult differs from the embryonic characters enumerated above, viz., from (4) to (9).

EXPLANATION OF PLATES

PLATE XXX. Hatching of *Crocodylus porosus* (Photographs).

Fig. 1.—Snout tip protruding sideways, note first crack on side of egg × ⅓

Fig. 2.—Snout correctly oriented, first crack lies close to table. Blood vessel across snout × ⅔

Fig. 3.—Animal abandoning egg shell. Umbilicus seen between egg shell and base of tail × ⅔

PLATE XXXI. Ossification in Stage B of *Crocodylus porsus* × 4⅓.

1, premaxillary; 2, maxillary; 3, nasals; 4, lacrymal; 5, prefrontal; 6, frontal; 7, postorbital; 8, interparietal; 9, squamosal; 10, quadrate; 11, quadratojugal; 12, jugal; 13, articular; 14, surangular; 15, angular; 16, hyoid; 17, dentary; 18, splenial; 19, interclavicle; 20, scapula; 21, humerus; 22, dorsal ribs; 23, gastralia; 24, eighth abdominal rib or prepubis; 25, pubic bone.

1

2

3

Hatching of *Crocodylus porosus* × $\frac{3}{2}$

Ossification in twenty six day embryo of *Crocodylus porosus* × 4

A New Crocodile from Ceylon

BY

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(With Two Plates and Three Text Figures.)

Early herpetologists of the British Museum, who had only two imperfect skulls of the Ceylon swamp crocodile on which to base their conclusions, considered this animal identical with the Indian swamp crocodile *Crocodylus palustris* Lesson. Comparison of the two forms now reveals distinct subspecific differences and as this examination is by no means exhaustive, it is possible that the two animals deserve separate specific rank; more particularly as the specific differences between many crocodiles, would, in the case of smaller animals, be considered by some to be of almost negligible importance. For instance the Madagascan crocodile *C. robustus* [1] Vaill. et Grandid. differs chiefly from the Indian *C. palustris* in its larger number of dorsal scutes and more completely webbed hind toes (Boulenger 1889, p. 286). The occurrence of several fossil broad-snouted crocodilians in Australia (Longman 1925) and the prevalence of living broad-snouted forms in the southern hemisphere suggests that the modern broad-snouted forms spread northward from southern ancestors; this view is supported by the higher specialization of the more northern Indian swamp crocodile as indicated by the scutes of this form being fewer and more differentiated than in the Ceylon species.

According to Boulenger (1890, p. 5) the Indian swamp crocodile has the dorsal scutes arranged ' in 4 (rarely 6) longitudinal series, those of the two median rows being usually considerably broader than long '. This description, while appropriate for the Indian species, is not entirely

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[1] Gray (1874) is definite that one Madagascan crocodile is a distinct living species. Voeltzkow (1892) states that when in Madagascar he saw one species and heard of another which was short headed and inhabited jungle rivers. Barbour (1918) considers *C. robustus* to be only valid as a fossil species. The skull he figures is rather similar to the skull of the Ceylon swamp crocodile.
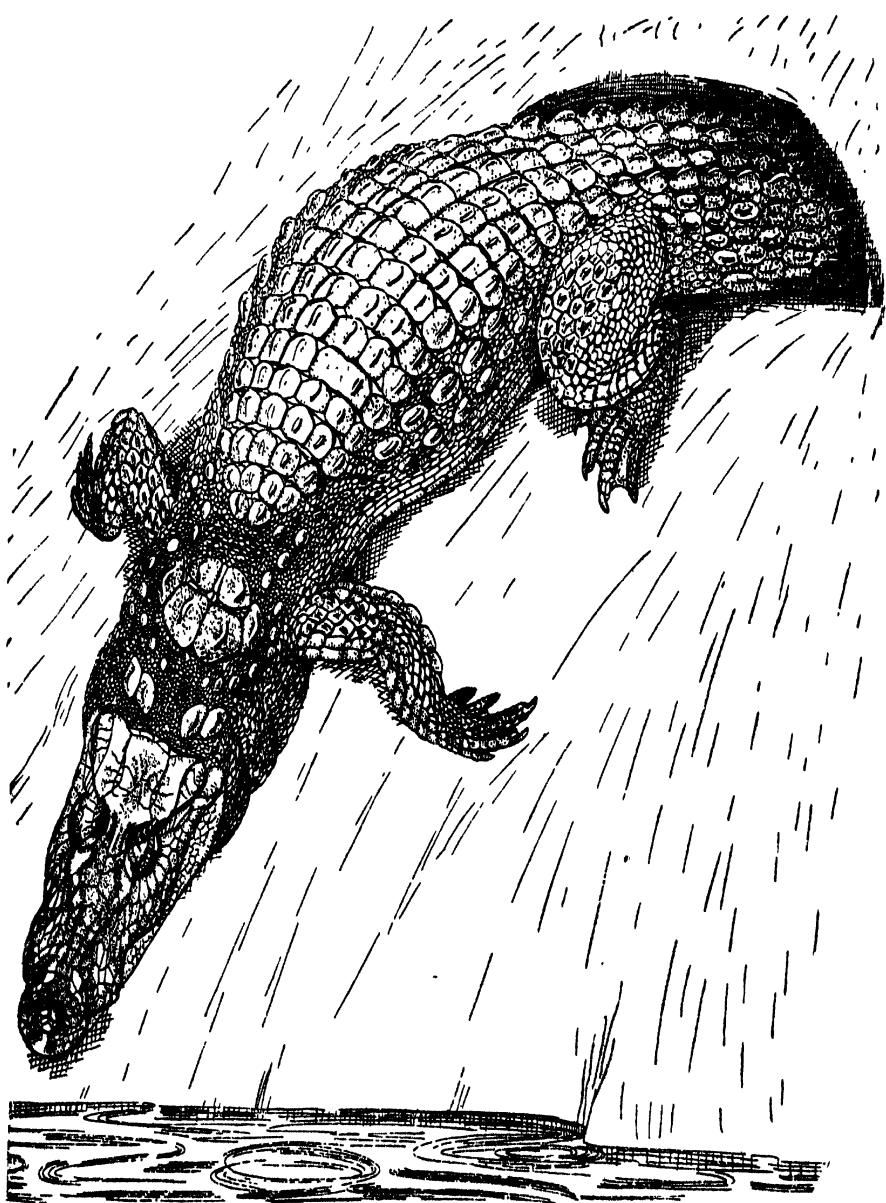
P. Deraniyagala del.

Fig. 1. *Crocodylus palustris kimbula* sub-sp. nov. × ½ emerging
from burrow. Mirigama × $\frac{1}{12}$

applicable to the Ceylon form, which usually possesses more transverse dorsal rows with six contiguous scutes than with four, while the scutes are subequal, with only an occasional one enlarged (Fig. 1). It is also
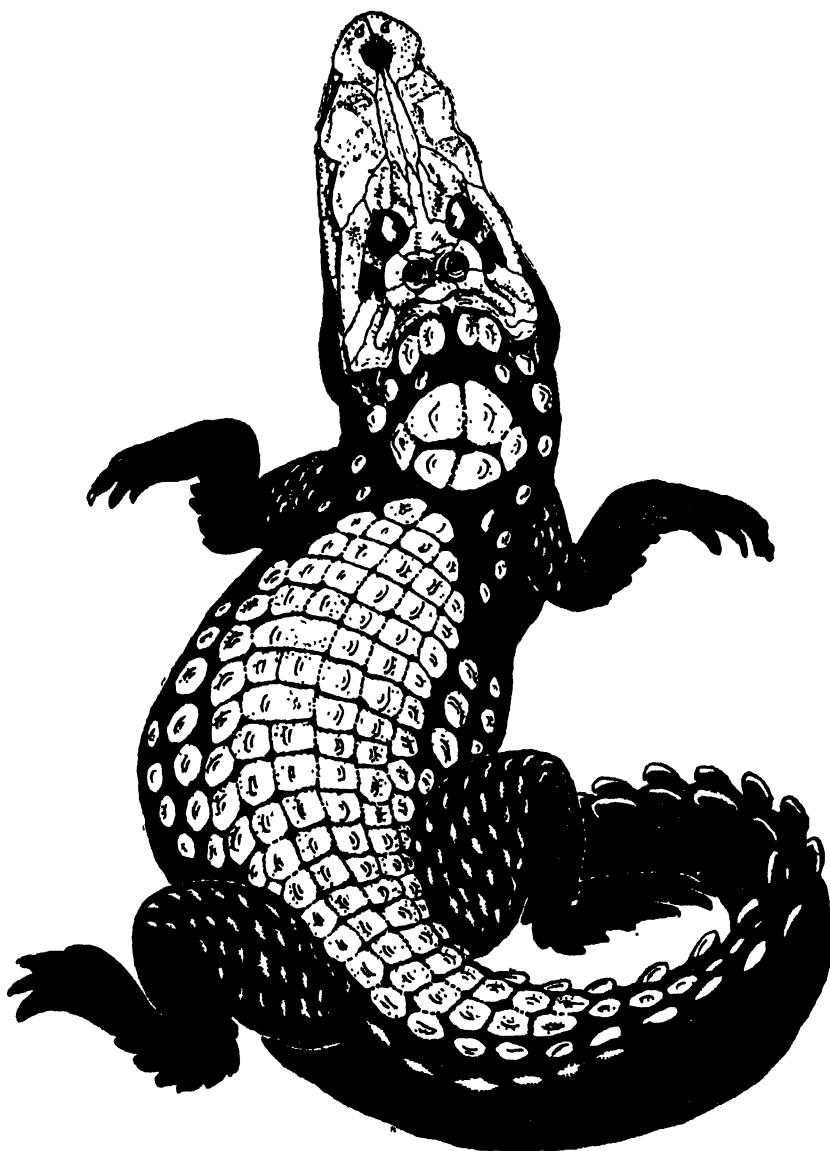
P. Deraniyagala del.

Fig. 2. Osteoderms of adult *Crocodylus p. kimbula* from Viravila S. P. × $\frac{1}{10}$.

known that the Indian form never attacks man and lives ' usually if not always above the limits of salt water ' (Smith 1931, p. 48), whereas the Ceylon form frequently attacks man and is not uncommon in salt lagoons (Deraniyagala 1930, p. 92). Consequently it is now suggested that the swamp crocodile of Ceylon be separated from the Indian as a subspecies and named *kimbula*, from the Sinhalese signifying ' crocodile '.

The following table shows the number of transverse dorsal rows comprising 4, 6, 7 or 8 contiguous scutes in each crocodile examined from Ceylon and India. The rows which were counted as far back as the last above the hips, usually numbered 17 but 16 and 18 also occurred.

TABLE I *Dorsal rows with contiguous Scutes* [1].

India[2]				Ceylon			
Crocodylus palustris palustris Lesson.				*Crocodylus palustris kimbula* sub-sp. nov.			
Serial No. of Crocodile	4 Scuted rows	6 Scuted rows	7 Scuted rows	Serial No. of Crocodile	4 Scuted rows	6 Scuted rows	7 Scuted rows
1	10	2	0	(1)	(6)	(4)	0
2	9	6	0	2	5	8	3
(3)	(6)	(6)	0	3	4	9	2
4	11	1	0	4	4	6	1
5	9	0	0	5	4	8	2
6	5	4	0	6	6	5	1
7	8	1	0	7	4	11	0
8	9	1	0	8	3	6	2
9	7	3	0	9	5	5	2
10	7	5	0	10	4	8	0
11	11	2	0	11	3	9	0
12	7	3	0	12	5	10	0
13	7	3	1	13	6	2	1 { 1 of 8 scutes
14	7	3	0	14	3	9	0
15	12	0	0	15	4	10	0
16	10	3	0	16	4	11	0
17	9	0	0	17	5	10	0
18	8	3	0	18	4	7	1
				19	4	8	0
				(20)	(8)	(6)	0
				21	5	6	1
				22	8	6	1
				23	4	12	0
				24	4	11	0

[1] Numbers within brackets denote individuals which are more or less intermediate or resemble those of the other subspecies.
[2] Specimens 14 to 18 were examined at Madras, Prince of Wales and Baroda Museums.

The graphs (Fig. 8) represent the numerical ratio of four scuted transverse rows to six scuted rows in eighteen Indian and twenty-three Ceylon crocodiles. The ratio for each individual is plotted directly above that animal's serial number. The latter in this instance is in ascending order of ratio and differs entirely from the serial numbers of the table I. The ratios are given in the following table.

TABLE II *Scute ratios*

Serial No.	Indian	Ceylon	Serial No.	Indian	Ceylon
1	1.0	0.33	13	8.0	0.5
2	1.25	0.33	14	9	0.5
3	1.4	0.36	15	9	0.5
4	1.5	0.36	16	9	0.57
5	1.75	0.36	17	11	0.71
6	2.33	0.36	18	12	0.71
7	2.33	0.37	19	—	1.0
8	2.33	0.4	20	—	1.1
9	2.66	0.4	21	—	1.33
10	3.33	0.45	22	—	1.5
11	5.0	0.5	23	—	1.5
12	5.5	0.5			
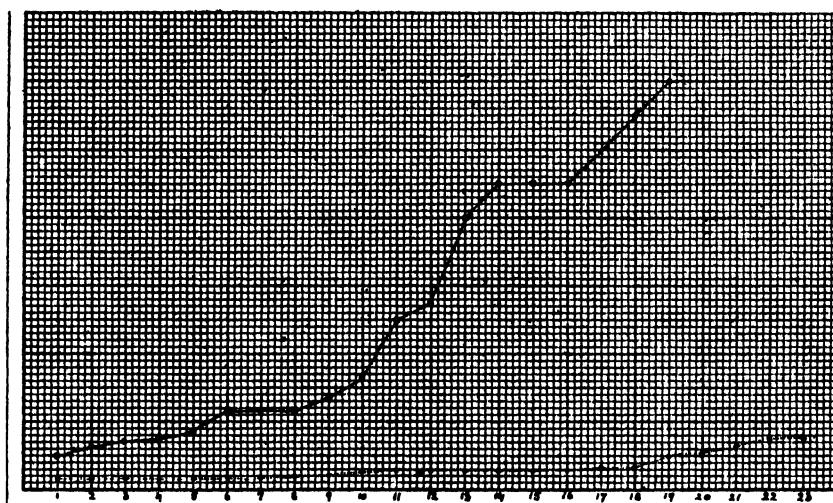
Fig. 8.   Ratio of 4 to 6 scuted transverse dorsal rows.   *C. p. palustris* continuous line *C. p. kimbula* broken line

Features which usually distinguish the Indian and Ceylon swamp crocodiles are as follows: —

A.   *Indian swamp crocodile.*

    (1) More transverse dorsal rows with four contiguous scutes than with six; rows with seven are rare.

(2) Two median longitudinal rows of conspicuously widened dorsal scutes (Plate XXXII, Fig. 2).

(3) No strongly enlarged ventral collar of scales (Plate XXXIII, Fig. 2).

(4) Lives ' usually, if not always above the limits of salt water ' (Smith 1931).

B. *Ceylon swamp crocodile.*

(1) More transverse dorsal rows with six contiguous scutes than with four rows with seven not uncommon and occasionally a row with eight.

(2) Dorsal scutes subequal; only a few isolated ones enlarged (Fig. 1).

(3) A ventral collar of scales which are usually about twice as deep as the surrounding scales (Plate XXXIII, Fig. 1).

(4) Not uncommon in salt water (Deraniyagala 1930).

Genus **Crocodylus**

Crocodylus Gronov 1763. *Zoophyl.* fasc. 1. p. 10
Crocodylus Laurenti 1768. *Syn. Rept.* p. 53 (type *niloticus*)

Seventeen to nineteen upper and fifteen lower teeth on each side, fourth mandibular tooth fits into a notch in upper jaw. Nasal aperture undivided. Two pairs of temporal openings. Splenial bones do not enter symphysis. Osteoderms dorsal, carinate, juxtaposed, with some sutured; as numerous as the dorsal scutes, and in four or more longitudinal series.

Crocodylus palustris kimbula sub-sp. nov.

Crocodilus palustris Lesson 1834 in *Belang Voy., Ind. Or. Zool.*, p. 305 (type loc. Ganges)
    Kelaart, 1852. *Prod. Faunae Zeylanicae* p. 183
    Tennent, 1861. *Nat. Hist. Ceylon*, pp. 284, 322
    Gunther, 1864. *Rept. Brit. Ind.* p. 61, pl. 8
    Annandale, 1912. *Rec. Ind. Mus.* VIII, p. 38
    Smith, 1931. *Fauna Brit. Ind.* I, p. 47
Crocodilus palustris Deraniyagala, 1930. *Ceylon J. Sci.* (B), XVI, pl. XIV
Crocodilus bombifrons Gray, 1844. *Cat. Tort. Croc., etc.*, p. 59 (type loc. India; Brit. Mus.)
    Kelaart, 1852. *Prod. Faun. Zeylanicae* p. 184
Crocodilus trigonops Gray, 1844. *Cat. Tort. Croc., etc.*, p. 62 (type loc. India; Brit. Mus.)
Crocodilus vulgaris var. *indicus* Gray 1831. *Syn. Rept.* p. 58 (Nom. nud.)

Sinhalese names Ḥalé Kimbula, Äḷa kimbula, Äli kimbula.

Snout widens with age; its basal width is contained 1.3—1.5 in its length. A short ridge at times extends from anterior angle of each eye along snout for an orbit length or less. Premaxillary teeth 5, sometimes 4, maxillary teeth 14, mandibular teeth 15. Postoccipital scutes well developed, 4 sometimes 6. Nuchals in two rows, the first of 4 to 6 scutes in a crescentic row, the second of 2. Sometimes a well developed row of 6-8 prenuchal scutes between postoccipitals and nuchals. Dorsal scutes subequal, an occasional one widened noticeably; they commence as two longitudinal contiguous series and may increase to as many as eight posteriorly; usually 5 to 6 rows with their osteoderms sutured together in a series of 16-18 usually 17 transverse rows. About 35 large scutes and scales round body at eighth transverse dorsal row. Caudal crest becomes uniserial from behind the thirty-fourth transverse row of dorsal scales. Cnemial fringe developed, toes three quarter webbed. Ventrally an enlarged collar of scales bordered anteriorly and posteriorly by scales only half as long. The two median scales of the collar usually partially separated from one another by an anterior and posterior scale. Skull with premaxillo-maxillary suture comparatively straight or feebly wavy. Palatine bones sometimes do not project beyond the palatal vacuities; supratemporal fenestra rather circular, sometimes triangular, well developed, with bony rims and separated from the orbit by a wide postorbital bone. Mandibular symphysis ends at level of fourth tooth; the splenial ends under the sixth tooth. Animal attains to over 4 m. in length.

Colours. Dorsally a drab olive-green with a large ∧ shaped dark mark near shoulders, followed by about three or four alternate broad, dark brown or black bands across body and nine to twelve on tail. Large oval spots on sides and limbs. Ventrally white with traces of brown cross bands, especially on throat.

Type. An adolescent, 127 cm. long, in the Colombo Museum

Reproduction. Lays about 6 to 25 hard-shelled eggs which vary in size and number according to the animal and range from 60 × 37 mm. to 86 × 52 mm. They are buried in the sand away from mud. Eggs removed from the original nest hatched in about three months.

Distribution. Found all over the low country of Ceylon, prefers slow-flowing or sedentary water. Not uncommon in salt lagoons, *e.g.*, at Elephant Pass, Tamblegam, Mullaittivu and along the lagoons of

the south.   Common at Mirigama (about 500 ft.) and at Kokare Vila [1]. It is a gregarious form and often excavates burrows in the bank. During droughts it aestivates either in such a burrow or with others under rocks, deep in the jungle.

I wish to express my indebtedness to Mr. H. W. Parker of the British Museum for his kindness in sending me information on the collection of Ceylon crocodiles in his charge, and also to Dr. S. L. Hora of the Indian Museum, Calcutta, for enabling me to examine 18 embryos and young of the Indian swamp crocodile.

I am also indebted to the following gentlemen who very kindly helped me with specimens:—Mr. A. E. Christoffelsz of the Ceylon Civil Service, Ratemahatmayas L. B. Nugawela and J. H. Illangantilleke, Messrs. J. R. P. Perera and R. D. Bandaranayake and Dr. P. E. Pieris, Trade Commissioner.

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EXPLANATION OF PLATES.

PLATE XXXII.

Fig. 1.—Crocodylus palustris kimbula ssp. nov. × $\frac{7}{10}$ (from Nikaveratiya) dorsal view

Fig. 2.—Crocodylus palustris palustris × $\frac{7}{10}$ dorsal view

PLATE XXXIII.

Fig. 1.—Crocodylus palustris kimbula ssp. nov. $\frac{7}{10}$ ventral view showing collar

Fig. 2.—Crocodylus palustris palustris × $\frac{7}{10}$ ventral view showing collar

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[1] A lake 10 miles from the sea with an unusually high percentage of magnesium and calcium salts.
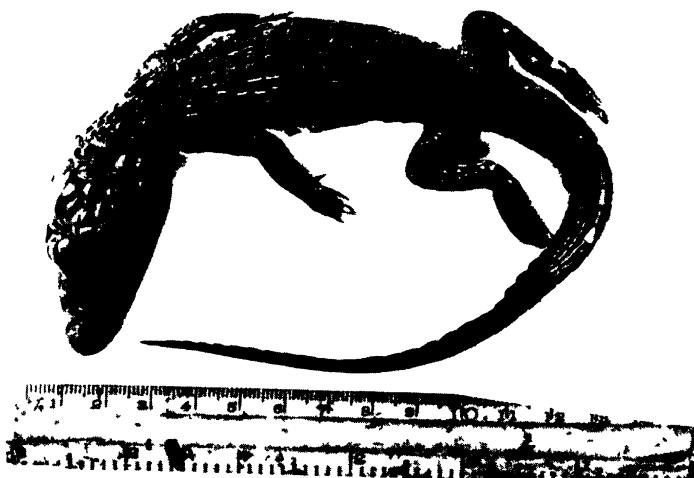
1.
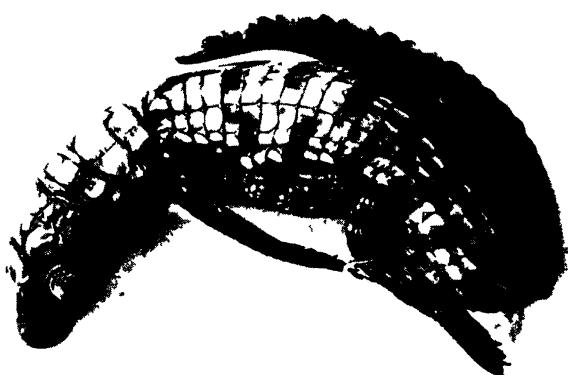
2.

1. *C. p. kimbula* × $\frac{1}{10}$ 2. *C. p palustris* × $\frac{5}{10}$

1.

The Affinities of the Lorisoids

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In recent years a number of important contributions have been made regarding the affinities of the lorisine or non-Malagasey " Lemurs ". All the authors concerned have unanimously agreed that these animals are structurally widely separated from the true or Malagasey Lemurs and have been so separated for a long period of geological time. Most of them also admit that the lorisines display close affinities with the Tarsioids. The authorities concerned in these views, however, have disagreed on the relations which the Tarsioids and both Malagasey and non-Malagasey " Lemuroids " bear to the higher Primates. Elliot-Smith (1929, 1930) holds that some " Lemuroid " was ancestral to all modern " Lemuroids " (Malagasey and non-Malagasey) as well as to the Tarsioids and through them to all higher Primates. He maintains, moreover, that the Catarrhine monkeys passed through a Platyrrhine as well as Tarsioid and " Lemuroid " phases in their evolution. The work of J. P. Hill (1932) supports Elliot-Smith's contentions, although it should be pointed out that the detailed account of the early stages of development of the Lemuroidea is based on the examination of lorisine material. The opposite views are held by the American school led by Matthew (1915) and Gregory (1916, 1920), who maintain that the monkeys had a diphyletic origin, Platyrrhines from one stock and Catarrhines from another. This idea has been more recently put forward by Tate Regan (1930 *a* and *b*) who suggests that the Lorisoids, as he terms them, are ancestral to the Platyrrhines, whilst the Lemuroids are ancestral to the Catarrhines. Tate Regan based his opinions (*a*) on geographical distribution and (*b*) on the results of the researches of Thornton Carter (1922) on the microstructure of the enamel of the Primates concerned. The most recent review of the position has been given by Le Gros Clark in a valuable treatise (1934 *b*) in which,

in the main, he adheres to the opinions of Elliot-Smith. In this work the Proto-lemuroids and the Proto-tarsioids are indicated as separating from the basal Primate stock at the very beginning, and on palaeontological grounds this author does not regard one as in any way ancestral to the other. Further, it is maintained that the Proto-lemuroids almost immediately diverged into the two branches represented by the lemuriform and lorisiform types of to-day.

In Le Gros Clark's work numerous scattered references to the structure of the Lorisoids are made, and in some cases comparison is made with that of the more typical lemurs.

Without becoming embroiled in the disputed question of the possible diphyletic origin of the monkeys, it is proposed, in the present contribution, to review the position held by the lorisine forms so as to assess, if possible, more accurately than hitherto, their relation to other primitive Primates. The paper is based on a preliminary contribution (1934) made by the author at the Aberdeen meeting of the British Association. At the outset it is necessary to state that, without any predisposition to adopt Tate Regan's views, it will be convenient to accept his terminology for the groups concerned, confining the use of the name ' Lemuroidea ' to the Madagascar animals, and referring to the non-Malagasey forms as Lorisoidea.

THE LORISOIDEA

The Lorisoidea comprise what are in popular parlance referred to as the slow lemurs. They form a fairly homogeneous, group distributed partly on the African mainland and partly in southern Asia. None is found in Madagascar in which island all the Primates are referable to the Lemuroidea. As a group, the Lorisoids are more primitive and generalized than the living Lemuroids. There are five or six genera forming a series of ascending degrees of specialization. The most primitive, and at the same time the least known, is the type-genus *Loris*, consisting of one species *L.tardigradus*, the Slender Loris, with several local races confined to Ceylon and the extreme south of India (see Hill, 1933). Next in order is the closely related *Nycticebus*, of which several forms occur all over the Malayan region, from Eastern Bengal to China, and in most of the Malayan islands. Very close to this, is the group of Pottos of the African mainland, comprising *Perodicticus* which extends across tropical Africa and the less well known *Arctocebus* (golden pottos) of Old Calabar.

Judging from a photograph of the living animal recently published in the *Illustrated London News* (December, 1934), *Arctocebus* would appear to resemble the Slender Loris much more than had hitherto been supposed. Finally come the more active and more highly specialized galagos of which several genera have been made by different authors. The most recent revision by Schwarz (1931) places all but one in the typical genus *Galago*, of which only four species are allowed. The remaining species forms the genus *Euoticus* which is distinguished by some details of the nails and teeth. By most modern authors the Lorisoid series is divided into two sub-groups usually labelled as subfamilies, Lorisinae to include the Oriental forms and the pottos, and Galaginae to include the Galagos. The Oriental lorises and the golden pottos are tailless; *Perodicticus* has a short tail; but the galagos have long bushy tails similar to those of the Lemuroidea.

There are no fossil genera that can be decisively referred to the Lorisoidea. Tate Regan refers the members of the fossil family Omomyidae to the Lorisoidea; but most writers place them with the Tarsioids. Le Gros Clark places the Omomyidae at the foot of the Tarsioid tree with hypothetical radiations into both Old and New Worlds. *Pseudoloris* is regarded as a fairly advanced Tarsioid coming off the main line leading to *Tarsius* itself. *Pronycticebus*, once thought to be a Lorisoid has been shown by Le Gros Clark (1934 a) to be a very primitive Lemuroid of the family Adapidae.

It is interesting and important to note at this stage, that the living Lemuroidea as a whole are vastly more specialized animals than any Lorisoid. Still more important is the fact that subfossil forms described by Standing (1908) show even more specialization than the living forms. Among the living representatives of the group, the subfamily Cheirogaleinae, or mouse-lemurs, are the most generalized and present a number of characters found otherwise only among the Lorisoids.

STRUCTURAL PECULIARITIES

In the following account the numerous structural peculiarities of the Lorisoids as found scattered in the literature are reviewed. The account is amplified by reference to the conditions in *Loris*, which, as already pointed out, is the most primitive member of the group, and the one least referred to in the literature. Many of the peculiarities mentioned have also been confirmed in *Nycticebus*, of which genus a full anatomical monograph has not yet appeared.

1. External Features

All Lorisoids are provided with a dense coat of woolly hair similar to that of Lemurs. Wool is replaced by true hair on the face. Elsewhere true hairs are scanty, except in very young animals on which long wiry hairs are everywhere mixed with the woolly coat. The rhinarium, palms and part of the soles are naked.

The rhinarium, as in Lemuroids, is naked and moist, and the nostrils slit-like. In the Tarsioids on the other hand, the nostrils are haplorhine as in monkeys.

The external ear is specialized in all Lorisoids. Pocock (1918) sums up the situation by stating that the simplest ears among Lemurs (including Lorisoids) are those of *Lemur* and *Cheiromys*. He adds that ears with greatly expanded and ribbed pinnae and valvular supratragus are derivative and specialized structures. According to this *Tarsius* has the most advanced form of pinna, but is linked to that of *Cheirogaleus* by the ears of *Galago* and *Microcebus*. The gap between *Galago* and *Microcebus* can be bridged by the ears of *Nycticebus* and *Perodicticus*. Apparently all the Lorisoids have a pinna capable of being folded, and marked, in the unfolded state, by a number of transverse ribs. *Cheirogaleus* has the ribs, but it is not definitely known whether folding occurs. *Loris*, *Nycticebus* and the pottos have not an expanded pinna, but nevertheless the ribbing is shown and in the first two genera the pinna is capable of folding. In these genera too there is a tendency to the atrophy of the tragus and for the poor development of the antitragus. On the contrary the supra-tragus is highly developed and valvular. In addition, *Nycticebus* and *Arctocebus* (Huxley 1864) have two transverse, folds running across the hollow of the pinna. In *Loris* these are further elaborated to form prominent shelf-like processes. *Galago* has the most expanded pinnae of the whole group, and in this genus the folding reaches its maximum.

With regard to vibrissae the Lorisoids differ considerably from the Lemuroids. In the latter group the primitive condition prevails, sinus hairs being numerous and long on the face, further sets being developed on the carpus. Most primitive of all is the condition in Cheirogaleinae in which all the facial groups are represented. The Lorisoids agree with the Tarsioids in having the facial vibrissae poorly developed and the carpal set completely absent. The facial groups are best developed in *Galago*, but even here the interramal tuft is invariably absent, whilst the genal tuft is but poorly represented. In

Nycticebus and the pottos they are still more rudimentary, whilst in *Loris* there are only three short sinus hairs on each side of the muzzle.

The presence of special skin glands on the fore-limb in Lemuroids seems to be one of their peculiar specializations. No gland of this type occurs in any Lorisoid.

The naked parts of the hands and feet are on the whole less primitive than in the Lemuroids, but in both there has been a peculair specialization of the digital formula, so as to produce a forceps-like structure capable of exerting a sustained grip on tree-branches, etc. This specialization consists of an enlargement of the pollex and hallux, and of an elongation of the fourth digit, so that digits I and IV form the two limbs of the forceps arrangement. The second and third digits tend to be shortened, but this shortening is not very marked in any Lemuroid. In Lorisoids, however, the second and third digits undergo marked shortening and in some genera are atrophic or absent. In *Loris* and *Nycticebus* the second digit is very short on hand and foot. In both the conditions are present early in foetal life. In the pottos the second and third digits are reduced to mere stumps, the extreme condition being found in the hand of *Arctocebus*. *Galago* departs least from the Lemuroid condition in respect of the digital formula.

In Lorisoids, as in Lemuroids, the second digit on the foot is invariably provided with a sharp claw instead of the usual flat nail.

As regards the palmar and plantar pads, in Lemuroids, especially in *Cheirogaleus*, the primitive mammalian pads are distinctly marked out. There is a tendency in Lorisoids for the divisions between the pads to be smoothed out. This is especially so in *Nycticebus*.

2. The Skull

In the skull are to be found some of the most interesting and constant differences between the Lemuroids and Lorisoids. The cranium in all genera tends to be relatively large and globular, especially in the young. The face, apart from the orbital region, is much reduced. The orbital region approaches that of *Tarsius* in size, and also in the fact that the orbital axes face directly forwards. The enlargement of the orbits encroaches on the nasal region, which is thus reduced, and is at the same time shortened anteroposteriorly, though not to the extent seen in *Tarsius*. In all these phenomena the different genera exhibit gradations. *Galago* has the skull shaped most like that of a Lemur and the eyes least hypertrophied. *Loris* and *Nycticebus* are at the other extreme.

The following are the main detailed distinctive features of the Lorisoid skull : —

The premaxillae are small in correlation to the reduction in the incisor teeth. They are forwardly produced so that the tip of the snout is anterior to the mouth. The maxillae are larger and share moderately in the formation of the orbital margin. They articulate with the premaxilla, nasal, malar, lachrymal, os planum and palate bones on each side.

The orbits are large and directed forwards and somewhat upwards. The bony margin is complete, but the cavities are not shut off from the temporal fossa. The bony rim, however, is broader than in any Lemuroid. The inner wall of the orbit has lachrymal and os planum in its composition. The union between the os planum and maxilla is incomplete leaving a gap anteriorly termed the ethmo-maxillary fissure (Hill, 1933). This is not present in Lemuroids. The lachrymal is very small, but never absent as stated by Le Gros Clark (1934 b). The lachrymal canal opens on the orbital margin, not outside as in Lemuroids, nor inside as in monkeys. The two orbits are separated by a thin partition of bone only. The infraorbital canal and foramen are single in all Lorisoids, but double in Lemuroids.

In the nasal fossa there are naso- and maxillo-turbinals and at least four ethmo-turbinals. The first of these is invariably large and completely covers the maxillo-turbinal. (Tate Regan and Le Gros Clark).

In the cranium the most remarkable distinctive features are related to the tympanic bulla and associated structures. In Lorisoids the ectotympanic element lies outside the bulla (Forsyth Major, 1901). In this character the Lorisoids resemble the Tarsioids and differ materially from the Lemuroids. The tympanic ring has become expanded and contributes, with the tympanic expansion of the petrosal, to the formation of the bulla wall. In *Nycticebus*, and still more in *Loris*, the ring is also produced laterally as a short tubular osseous meatus. The arrangement of certain small foramina in this region also serves to separate the Lorisoids sharply from the Lemuroids. There is a foramen lacerum medium, as in monkeys, which conveys the internal carotid artery directly into the cranium. In Lemuroids this foramen is absent. There is also a minute foramen on the posterior wall of the bulla for the transmission of the stapedial artery, a small twig from the internal carotid. The interior of the bulla is subdivided by a septum into two compartments. In Lorisoids the septum is incomplete, but in *Tarsius* it is complete (Woollard, 1926).

The hyoid bone of Lorisoids is similar to that of Lemuroids, with a long anterior cornu and a short posterior one.

3. Axial Skeleton

In all Lorisoids the vertebral column is elongated. This applies more especially to the thoracic and lumbar regions of the column, and affects *Loris* more than the remaining members of the group. The cervical region is relatively short and possesses the usual seven vertebrae. The total number of pre-sacral vertebrae is always large, but varies in the different genera and to a less extent among individuals. *Loris* and *Nycticebus* have the highest number, commonly 30, but occasionally there are 31 and less frequently 29 or only 28. *Perodicticus* also usually possesses 30, but some specimens have as few as 27. *Galago* resembles the majority of Lemurs in having only 26. *Tarsius* also most commonly possesses 26 (see Straus and Wislocki, 1932 *b*). Of these pre-sacral vertebrae those bearing ribs, *i.e.*, thoracic vertebrae, are interesting on analysis. Straus and Wislocki (1932 *b*) state that in *Nycticebus* and *Loris* the majority of individuals possess 16 pairs of ribs. A fair number have only 15 pairs, but a few possess 14 pairs, whilst others have as many as 17 or even 18 pairs. All my specimens of *Loris* had either 14 or 15 pairs of ribs, and of these nine pairs reached the sternum directly and four pairs attained the cartilage of the preceding pair, leaving three or two pairs of floating ribs. *Galago* has generally 13 pairs, but occasionally 14. The Pottos possess the same number of ribs as *Nycticebus*. Compared with Lemuroids and Tarsioids, therefore, the Lorisoids tend to an increase in the total number of ribs.

Straus and Wislocki (1932 *b*) have further drawn attention to the fact that in the Lorises the spinous process of all the vertebrae incline backwards, *i.e.*, there is no anticlinal vertebra. I have confirmed this for *Loris*. *Galago*, however, appears to agree with the Lemurs in having an anticlinal vertebra. In a footnote the above authors state that an anticlinal vertebra has been noted by them in two skeletons of *Loris*.

The sacrum consists of three vertebrae of which only two articulate directly with the ilium. The number of post-sacral vertebrae is very variable, as is the development of the external tail. The active galagos have long tails with numerous vertebrae as in *Lemur*. *Perodicticus* has a short external tail. The remainder are usually described as tailless, but frequently there is a rudimentary external tail containing the tip of the coccyx, both in *Nycticebus* and *Loris*.

Straus and Wislocki also refer to the thoracic index. In Lorisoids this is usually above 100. In *Tarsius* 100 is the normal figure, but sometimes a higher figure is reached. Among the Lemuroids the index is always less than 100. *Galago* again finds a place among the Lemuroids rather than the Lorisoids. My specimens of *Loris* do not bear out this relation, for in this genus the thorax tends to be long and very narrow like a dog's. This character is not one of deep significance and seems to have a bearing on the normal posture and mode of progression and also on the speed at which muscular movements are carried out. Lorises and pottos are slow movers, whilst the galagos have become secondarily specialized as active leapers similar to *Tarsius*. Any resemblances between Galagos and Lemurs in this direction are to be regarded as due to convergence.

9. Appendicular Skeleton

The most striking peculiarity concerning the limbs of the Lorisoids is their free range of movement. This is especially so at the wrist, hip and ankle joints.

The clavicles are well-formed and slightly curved as in Lemurs. The scapulae resemble those of primitive mammals. The pelvis is long and narrow, with a wide sub-pubic arch and a large obturator foramen. There is a marked difference in the shape of the gluteal surface of the ilium among the lower Primates as indicated by Straus (1929). In *Nycticebus* this surface is flat. In *Loris*, as in *Tarsius*, it is convex. In Lemuroids the surface is concave. The condition in the African forms has not been recorded.

Of the long bones of the limbs, it is to be noted that the disproportion in total length of the hind limb over the fore limb in Lemuroids does not occur in Lorisoids, in which the limbs are subequal. Here again *Galago* is an exception on account of the secondary specialization of the hind-limb as a jumping organ.

The carpus in Lorisoids escapes some of the Lemuroid specializations of this region. The scaphoid is wide as in Lemuroids, but the semilunar is not narrow as in the latter. The narrowing of the os magnum, so characteristic of Lemurs, is not pronounced in *Loris*. There is a small centrale. This is pushed somewhat laterally so as to prevent the os magnum from uniting with the semilunar. The unciform is a large bone, but does not reach the proportions seen in Lemurs and *Notharctus*. *Loris* has an additional bone, called by Subba Rau (1931) *ventrale*. It is an ossification in the anterior

annular ligament of the carpus. It is not so large as indicated in the diagrams of the last-mentioned author. A pisiform is present and relatively large. There is also a fair sized radial sesamoid. Correlated with the large pollex and its free mobility is a large trapezium, with an extensive distal facet, as in Lemuroids.

The tarsal region of all Lorisoids tends to be elongated in conformity with the tarsi-fulcrumating type of progression adopted by these animals (Morton, 1924). In *Galago* the hypertrophy of the tarsus approaches that of *Tarsius*, for both animals have adopted, independently, the same saltatory mode of progression. The less specialized pottos and lorises progress by placing alternately one foot in front of the other, getting the forward push from the tarsal region at each step. This involves a lengthening and strengthening of the os calcis and astragalus. The scaphoid (navicular) is also a well developed bone and overhangs the medial margin of the foot. The cuboid is long and narrow. The entocuneiform is large with a broad saddle-shaped facet for the base of the first metatarsal. The mesocuneiform is small, and the ectocuneiform medium in size. The latter is yoked to the dorsal aspect of the os calcis by a strong ligament. There is a small sesamoid bone in the tendon of the peronaeus longus.

5. Splanchnology

(a) Teeth

In dealing with this system mention may first be drawn to the teeth as these have formed the basis of so much speculation in discussing fossil forms of Lemuroidea.

The upper incisors are, as in Lemuroids, atrophic. The atrophy reaches a higher degree in Lorisoids than in Lemuroids. There are never more than two incisors on each side of the upper jaw, whilst in some species of *Nycticebus* they are reduced to a single pair. In all cases the lateral pair is smaller than the median pair, which is separated by a wide interval. The premaxilla is reduced in correlation with the atrophy of the upper incisors.

The lower incisors have attained the same specialization, as a fur-combing apparatus, as in true Lemurs. They are procumbent and styliform. The canine has become incisiform and lies alongside the lateral incisor. Gregory thinks the incisor condition is secondary to the state of the tongue. Le Gros Clark believes the opposite. It is

to be noted that the peculiar conformation of both upper and lower front teeth was present in the earliest Lemuroids, as well as in Lorisoids, indicating a very old evolutionary trend in the whole series.

The upper canines are often long and tusk-like. Especially in the male of *Loris*, and in both sexes of *Nycticebus*.

The upper premolars are reduced, as in Lemurs, to three on each side, the first of the typical mammalian series being absent. There is a prevailing tendency in many Lemurs to the molarization of the hinder premolars. This is figured in *Galago* by Le Gros Clark. It occurs also in *Loris* (Hill, 1933). According to Le Gros Clark in *Lemur*, *Loris* and *Perodicticus*, the upper premolars only possess two cusps, paracone and deuterocone, but in the case of the last molar of *Galago* the molarization process has introduced a metacone and an ormentary hypocone. *Nycticebus* also has the simple two cusped premolars. I have pointed out elsewhere (1933) that in *Loris*, however, there are three cusps on the two anterior premolars and an additional one on the last premolar. Such teeth are more advanced from the primitive condition than the simpler teeth of *Lemur*. In the lower jaw the most anterior premolar is shaped like a canine, as in Lemuroids. The second is also a peg-like tooth in *Loris;* but the third is molariform. In *Nycticebus* the hinder two premolars are both peg-like in the lower jaw. In *Galago* the third premolar has a small heel posteriorly with a short stout cusp surmounting it.

The upper molars of Lorisoids tend to be more complicated than those of the Madagascar Lemurs. In the latter these teeth are typically trituberculate, with a slight indication of a true hypocone in *Lemur*. In *Perodicticus* there is a minute hypocone, but this becomes conspicuous in *Nycticebus* and *Loris*, whilst in *Galago* the teeth are frankly quadricuspidate. Some of the fossil Lemuroids, especially *Notharctus* are quadricuspidate, but in these the hypocone is a false one due to splitting of the protocone. *Loris* has, besides the four main cusps, a variable number of accessory cusps.

The lower molars of Lorisoids are not discussed in the literature, although the differences from those of Lemurs are as outstanding as in the case of the upper teeth. The lemurine lower molar is characterized, as far as living forms are concerned, by the absence of the paraconid, and the shifting of the protoconid so that it lies opposite to the metaconid. The hinder part of the tooth consists of a raised and broadened talonid basin, with no definite cusps on its margins. The Lorisoids have evolved a complete quadrituberculo lower molar by the development of entoconid and hypoconid on the medial and

lateral margins respectively of the talonid basin, which in these forms is less broad than in Lemurs. In *Loris*, *Nycticebus* and *Galago* all four cusps are equal in size on the first two molars. In all these forms the last lower molar tends to be smaller, due to the narrowness of the talonid basin. In *Loris* all four cusps are present on this tooth and there is in addition a large hypoconulid at the posterior margin of the basin. The same condition occurs in *Nycticebus* and *Arctocebus* (Mivart 1864), but in *Galago* this last tooth is more like that of a Lemur, with a broad, shallow talonid basin and no well defined cusps bordering it.

(b) Microstructure of Teeth

The researches of Thornton Carter (1922) first drew attention to the important distinction between the microscopic structure of the tooth-enamel in Lorisoids and Lemuroids, and also attracted notice to the fact that the Lorisoids agreed in their tooth structure with the Platyrrhines, whilst the Lemuroids agreed with the Catarrhines. The work of Thornton Carter covered both living and fossil forms.

In Lorisoids the enamel pattern is such that the component enamel prisms have wavy edges and are separated by a larger amount of interstitial substance. The same occurs in *Tarsius*, in the Eocene *Hemiacodon* and also in all Platyrrhine monkeys.

In Lemuroids, recent and fossil, and also in Catarrhine monkeys, the enamel prisms have straight edges and are separated by a small quantity of interstitial substance.

Thornton Carter also studied the degree of penetration of the enamel by dentinal tubules. Here there seems to be no taxonomic relation, for among Lemuroids there is much variability from genus to genus. In Lorisidae, (excepting *Nycticebus*) penetration is rich. The same occurs in the Indrisine Lemurs and in the Cheiromyoids, recent and fossil. In Lemuridae penetration is slight.

It was on Thornton Carter's results largely that Tate Regan suggested that the Lorisoids were probably ancestral to the Tarsioids and the Platyrrhine monkeys; whereas the Lemuroidea represent the ancestral stock from which the Catarrhines evolved.

(c) Tongue

The tongues of the Lemurs and Lorises have been dealt with in detail by Sonntag (1921) and to some extent previously also by Pocock (1918). In both series of animals the tongue is provided with a sublingua, and this is armed with rows of denticles along its free margins.

The denticles correspond in position with the intervals between the mandibular teeth and have been usually regarded as a mechanism for removing fur, etc., with which these teeth would otherwise become clogged by virtue of their use in combing the coat. The structure of the sublingua, therefore, goes hand in hand with the arrangement of the lower incisors and canines. In *Tarsius*, where the mandibular teeth are normal, the sublingua is less developed and softer in consistency.

According to Pocock, in *Galago, Nycticebus* and *Perodicticus*, the sublingua is broader than in Lemurs, especially at the apex. This writer observed nine denticles on the sublingua of *Galago monteiri* and *Perodicticus ibeanus* forming in each case a continuous series. In *Nycticebus* there were seven denticles and the outer one on each side was larger than the rest and separated therefrom by a space.

Sonntag examined the tongues of all the genera of Lorisoids except *Arctocebus*, and conveniently tabulated the differences between them and the tongue in Lemuroids. The differences were constant and were considered by Sonntag to be of taxonomic importance. The facts are : (i.) in Lorisoids the vallate papillae from a triangle instead of a letter Y as in Lemuroids; (ii.) lateral organs are absent; (iii.) conical papillae increase gradually from apex of tongue to epiglottis, whereas in Lemurs they are small on the oral part and large on the pharyngeal part; and (iv.) the sublingua is tongue-shaped and provided with denticles along its anterior border, whilst the same organ in Lemurs is triangular, or lyrate with apical denticles only. It is important to note that in *Microcebus* Sonntag found the tongue to be of the Lorisoid type. The Lorisoid tongue resembles that of *Tarsius* more than that of the Lemuroids.

(d) *Peritoneum and abdominal alimentary canal*

The disposition of the peritoneum in Lorisoids is very primitive. The whole length of the abdominal alimentary canal is slung in mesenteries. The stomach has the usual dorsal and ventral mesenteries; the duodenum is free and the colon has a complete mesocolon. In *Loris* where the simplest arrangement prevails, there are adhesions of the two extremities of the transverse colon to the anterior aspect of the mesoduodenum. Between these two points the colon is bent ventrally as a simple loop, with a layer of peritoneum connecting the two limbs of the loop. In *Nycticebus* the colonic loop is spirally twisted on itself (Harrower, 1933) in a complicated manner. An intermediate condition is figured by Wood-Jones (1929) in *Galago*

mohili. Duckworth in collaboration with Elliot (1904) described a three-limbed colonic loop in *G. garnetti*. Le Gros Clark dismisses matters too vaguely when he gives all the Lorisoids, as well as *Indris*, as having an elaborately twisted spiral loop to the colon. *Microcebus* and *Cheirogaleus*, according to the last named author, have a simple colon, unlike other Lemurs, but resembling *Tarsius*. A caecum is present to the colon in all Lemuroids and Lorisoids, but there seem to be no definite constant features separating the caeca of the two groups.

The stomach differs in the two types. True Lemurs have an elongated stomach, with a narrow pyloric portion. In all Lorisoids the stomach is globular (Wood-Jones, 1929).

The liver in Lorisoids differs somewhat from that of the true Lemurs. There is, as in most Primates, no ' bare area ', the organ being slung by mesenteries from the diaphragm and abdominal walls. There is not such a great tendency for multilobulation in the Lorisoid liver as in Lemuroids. *Loris* and *Perodicticus* have a liver composed of three main lobes, right, central and left, of which the right is smallest and the left largest. *Loris* has, in addition, a large caudate lobe and a diminutive Spigelian lobe. The gall-bladder is invisible without dissection. The liver in *Nycticebus* has been compared by Beattie (1927) with that of *Hapale*, a primitive Platyrrhine monkey. Harrower (1933) described the liver in this genus in detail, stating that there were three main lobes, an almost hidden gall-bladder and a very deep oesophageal groove. The liver of *Galago garnetti* was described by Duckworth (1904) as large and multilobular, and with a large Spigelian lobe and caudate lobe. Le Gros Clark, quoting Nayak (unpublished thesis) indicates that the liver of *Galago* resembles that of *Tarsius* rather than that of the Lemurs, *i.e.*, not well lobulated; and with a shallower oesophageal notch than in Lemurs.

(c) Trachea

According to Wood-Jones (1929) the trachea of all Lemuroids (in the old sense) is characterized by the completeness of its cartilaginous rings. ' Even in such species as show a weakening of the posterior aspect of the rings ' says this authority ' there is apparently no discontinuity of cartilage '. Since that date the question has been gone into afresh by Straus (1931) who examined the tracheae of *Lemur*, *Galago*, *Perodicticus*, *Nycticebus* and *Tarsius*. Only in *Lemur* did he find complete cartilaginous hoops in the trachea. Various previous authors (*e.g.*, Duckworth, 1915, and Sonntag, 1924) had mentioned

complete rings in *Tarsius*. Possibly this genus is variable in this respect. There does not seem to be such variation, however, among the Lorisoids, I have examined the trachea of *Loris* and *Nycticebus* and find incomplete rings in both. In the former there was a large interval between the tips of the rings, especially in the lower half of the tube.

(f) Kidneys

The kidneys of all sub-pithecoid Primates are unipyramidal. Subba Rau and Hiriyannaiya (1930) described the kidney of *Loris* as being actually multipyramidal, although apparently unipyramidal in median coronal section. This description is entirely due to a misinterpretation of the appearances. All Lorisoids have a unipyramidal kidney but the form of the pyramid differs from that seen in the Lemuroid kidney and agrees with that described in the kidney of *Tarsius* by Straus (1934) and figured in *Galago* by Wood-Jones (1929). This type of kidney is charactersitic of the Lorisoids and *Tarsius*, and does not occur in other Primates. It consists of one large pyramid upon the summit of which open all the tubules from the kidney substance. The papilla is large and projects as a flat, tongue-shaped structure for a considerable distance into the pelvis of the ureter. If a section is taken coronally through the middle of the kidney, the whole extent of this large pyramid and its papilla is seen. If the section passes but a millimetre in front of, or behind, the middle, however, the tongue-shaped papilla is not seen, but instead the side wall of the renal sinus is exposed. At the bottom of this the tubules making for the pyramid will be cut across. These are arranged in clusters, giving a wavy outline to the cut edge of the renal sinus. It is this appearance that was mistaken by Subba Rau for a multipyramidal condition. If the other half of the section is examined, the whole tongue-shaped papilla will be found on it, and unless examined carefully will be mistaken for the opposite wall of the renal sinus. Careful examination will reveal that the structure can be pulled forwards as a flap, exposing the actual renal sinus wall behind it. This condition has been confirmed in both *Loris* and *Nycticebus*.

(g) Male Genitalia

The testes in Lorisoids descend into a scrotum, but in *Loris*, at any rate, they return to the inguinal canal during the non-breeding season. It would appear that this does not occur in *Nycticebus* or *Galago*.

Seminal vesicles are large, and undergo hypertrophy in *Loris* during the breeding season. Their ducts open into the prostatic urethra separately from the vasa deferentia. The prostate is a pear-shaped gland consisting of a single lobe in *Loris* and *Nycticebus*. In this the two forms agree with *Tarsius*, and differ from nearly all other Primates. *Galago* and the pottos do not appear to have been investigated in this connection, but their prostates are most probably also unilobular. The penis is provided with a simple baculum. No baculum occurs in *Tarsius*. The glans is smooth in all but the galagos, in which the surface is beset with stout grappling spurs as in some species of *Lemur*.

The spermatozoa of *Loris* are similar in appearance and structure to those of *Lemur*. Those of *Tarsius*, on the contrary, are described by Woollard (1925) as being singularly like the human sperm.

(h) Female Genitalia

The ovary lies in an ovarian peritoneal fossa in *Loris*, and there are strong ovarian and diaphragmatic ligaments in *Loris* and *Galago* (Duckworth, 1904).

The uterus is of the usual lower mammalian type, as in Lemuroids, *i.e.*, with large cornua and short, coiled Fallopian tubes. In this respect Lorisoids differ from *Tarsius*, in which there is a more solid median portion to the uterus, although cornua are still present. The tubes, in *Tarsius*, are shorter and wider.

It is in the external female genitalia that the greatest differences occur between Lemuroids and Lorisoids. In the latter there is a large clitoris without a bone, tunnelled throughout by the urethra, which thus opens on the glans. In Lemuroids, although the clitoris is large, it is grooved below like a hypospadiac penis, the urethra opening, as in monkeys, at the base of the clitoris just in front of the vagina. The two types are admirably figured by Wood-Jones (1929, p. 105).

(i) Mammary glands

In text-books, vague statements are made regarding the number of mammae in the different groups of lower Primates. Duckworth (1915) states that Lemuroids are provided with a single pectoral pair, but that an occasional abdominal pair is present. He was probably thinking of *Cheiromys*. It has usually been assumed that apart from this genus the pectoral pair was the only pair present. The same author

states that *Tarsius* has a pectoral and an inguinal pair. Mammae are not mentioned by Pocock (1918) or by Woollard (1925). All the Lorisoids so far examined seem to be provided normally with two pairs, the usual pectoral pair and an additional abdominal pair. This is true of *Galago* (Weber), *Loris* (Willey, 1906 and Hill, 1933) and *Nycticebus* (personal observation). It is unlikely that the pottos differ in this respect from the other Lorisoids. The whole group would thus appear to differ from all the Lemuroids except the aberrant aye-aye.

6. Angeiology

(a) Heart

It is only necessary to mention, in connection with this organ, the angle formed between the two lines (a) connecting the orifices of the superior and inferior venae cavae and (b) connecting the orifice of the superior vena cava with the apex of the heart. In *Loris*, as indicated by Subba Rau and Krishna Rao (1930) this is an angle of 44 degrees,— almost identical with the angle in *Tarsius*. In *Nycticebus*, as indicated in Weber's (1904) figure the heart lies more vertically and the angle measures only 35 degrees.

(b) Aortic Arch and branches

Wood-Jones (1929), in dealing with the systemic aorta of Lemurs, states that the arch is steep in pitch and gives off only two branches, innominate and left subclavian. In Lorisoids the pitch is less steep, and in *Loris* there are three branches, as in Man. In *Nycticebus* the arch is also broad, but I found only two branches as in Lemurs.

(c) Internal Carotid Artery

The mode of termination of the internal carotid (entocarotid) artery is intimately associated with the arrangements in the tympanic region of the base of the skull, and thus differs considerably in the two types of lower Primates. The matter is admirably summed up by Le Gros Clark (1934 b). In ordinary Lemuroids, the internal carotid vessel terminates at the base of the skull by dividing into two terminal twigs, the stapedial artery, and the *arteria promontorii*. The former runs up through the stapes to the roof of the tympanic cavity. The latter, which is a continuation upwards of the parent vessel, passes into the cranial cavity to supply the brain. The stapedial artery enters the tympanum through a foramen in the hinder wall of the bulla. The *arteria promontorii* is given off inside the bulla and is very minute, the major part of the blood supply of the brain coming from other sources (vertebral arteries). In the Lorisoids the antithesis exists.

The stapedial artery is minute, whilst the *arteria promotorii* is very large, and instead of taking a tortuous course in the tympanic cavity, proceeds into the cranial cavity through the foramen lacerum medium. Once inside the cranium the two carotids enter into anastomosis with the vertebrals to form a circle of Willis as in Man. The brain has therefore a better, as well as a more direct, blood-supply than in Lemurs.

The Cheirogaleinae, as in the case of the cranial foramina concerned, agree in the arrangements of these vessels with the Lorisoids rather than with the Lemuroids.

(d) Retia mirabiia

The proximal parts of the limb arteries, in both fore-limbs and hind limbs of the Lorisoids, are characterized by being split up into a number of longitudinal channels running parallel to one another. This condition forms one type of *rete mirabile*, and occurs in much the same form in certain Edentates (*e.g., Cholocpus, Bradypus* and *Cyclopes,* see Wislocki and Straus, 1932 *a*, who have compared the Lorisoid and Edentate limbs in this connection). The condition has been associated with the slow-moving, tight-gripping limb-muscles of lorises and pottos, and it is thus not surprising that it is absent from the active galagos. The feature would thus appear to be an adaptive one, and of little or no value in assessing relationships.

It must be remembered, however, that a number of observers (Vrolik and Burmeister quoted by Duckworth, 1915) have recorded retia mirabilia in the brachial and femoral vessels of *Tarsius,* whose mode of life is similar to that of *Galago.* Duckworth (loc. cit.) and Woollard (1925) do not mention this fact in their dissections of this animal.

7. Myology

The only point in the muscular system to which attention has been directed is the state of the biceps muscle of the brachium. Howell and Straus (1931) have studied the brachial flexor muscles in a series of Primates and arrived at the conclusion that only the lorises had a biceps with a single head. The coracoid head is according to them absent in *Loris* and *Nycticebus,* and I have confirmed in both genera. The condition in *Perodicticus* has not been recorded, but in *Galago* both heads are present. This character would appear to fall into the same category as the retia mirabilia.

8. Special Sense Organs

(1) Nasal Fossae.

The nasal part of the face is much reduced in Lorisoids, though not to the extent seen in *Tarsius*. No Lorisoid, however, has the elongated snout of the Lemuroids. The shortest faces are to be seen in the smaller Galagos. The rhinarium has already been discussed. In the nasal fossa the Lorisoids differ from the Lemuroids in the disposition of their turbinate bones, the first ethmo-turbinal of the former being very large and hiding the maxillo-turbinal completely.

(2) Visual Organs.

The eyes in all Lorisoids are inordinately large, approaching the condition seen in *Tarsius*. Like *Tarsius* they are nocturnal animals, thus differing from the majority of true Lemurs, which are at any rate partly diurnal. The largest eyes relatively are found in *Loris*, *Nycticebus* and the pottos have eyes somewhat less, and the galagos still less in relative size. The eyeball in *Loris* is actually the same size as in *Nycticebus*, though the latter is a much larger animal.

In all the genera so far examined the cornea forms a large proportion of the surface of the eyeball, and has a very marked curvature. Thus, in *Loris* out of a total of 15.5 mm. for the antero-posterior diameter of the globe, the corneal depth accounts for 4.5 mm. The lens too is large and relatively globular. It is half as big as the vitreous body and sunk deeply into the latter. A tapetal layer is present in the choroid of *Loris* (Hill, 1935) and *Nycticebus*, and probably also in the other genera. The retina has no definite macula on ophthalmoscopic examination in *Loris* (Hill, loc. cit.), although an artery corresponding in position to a macular artery was found. In *Tarsius*, Woollard described from histological examination what he calls a *primordium maculae*. The axes of the eyeballs in *Loris* and *Nycticebus* indicate a considerable overlap of the visual fields. The retina of several Primates has been studied in detail by Woollard (1927). Although there is considerable variation in the structure of this organ in the lower Primates, there appear to be two main types of retina, the diurnal and the nocturnal. The latter occurs in animals of nocturnal and crepuscular habits and always lacks a fovea. The retinae of all the Lorisoids and of *Tarsius* appear to be of the nocturnal type. The true Lemurs also appear to possess the same retinal structure. Among Anthropoids, the primitive Platyrrhine monkey *Aotes* is unique in having a nocturnal type of retina lacking both macula and fovea.

The fibres of the optic nerve are connected centrally with the external geniculate body. This object has been studied comparatively by Woollard (1926) and by Woollard and Beattie (1927). The conclusions arrived at suggest that there is no correlation between the structure of the external geniculate body and the type of retina present, but that the affinities of the genera as adduced from other parts of their anatomy are confirmed by the study of their external geniculate bodies. There are two types of external geniculate body. In type I the body is divided into two portions of different pattern, a dorsal laminated part and a ventral non-laminated part. In type II the whole structure is laminated. Type I occurs in *Tarsius*, *Perodicticus* and in the Platyrrhine *Aotes*. Type II occurs in *Galago*, *Nycticebus* and the Lemuridae. The separation of *Perodicticus* from the other Lorisoids does not seem to agree with Woollard and Beattie's statement that the structure of the external geniculate body is in accordance with the zoological affinities of the forms examined. The external geniculates of *Loris* and *Nycticebus* are receiving attention in this department, and I hope to publish a separate note on this subject.

9. Development and placentation

J. P. Hill (1928 and 1932) has studied the early stages of development and the placentation in *Loris* and bases his data for the development of the " Lemuroids ", inadvisedly in my opinion, on this work, together with some observations derived from Hubrecht's (1907) work on *Nycticebus*. He admits that the lemuriform lemurs have not been studied in this connection. The placentation of the latter is, however, well-known from the work of Turner (1877), whilst *Chiromys* has also been studied by Hill and Burne (1922) In all the text-books, therefore, one finds that Lemurs, in the wide sense, are characterized by the diffuse nature of the placenta, whilst monkeys and human beings have a placenta at first diffuse, but later restricted to a discoidal or bidiscoidal area of the chorion. *Tarsius* agrees with the monkeys in its placentation, whereas the Lorisoids agree in the main with the true Lemurs, although, as Hill remarks, there are minor differences between the two types, as well as other differences from genus to genus. A great problem has arisen as to whether the simple Lemuroid type of placenta is ancestral to the more complicated placentae of the Tarsioids and Anthropids. Unfortunately the Tupaioids, a group of insectivorous mammals from whom the early Primates are commonly believed to have been derived, are endowed with a different type of placenta from the Lemuroids, and more akin to the Tarsioid type of placenta. Some advocate that the lemuroid

placenta has been secondarily simplified (*e.g.* Wislocki, 1929), whilst Hill (1932) maintains that the lemurine placenta is the primitive condition and represents a stage that has been passed through by the Tarsioids during their evolution. Le Gros Clark (1934) rejects the placenta as a factor to be considered in classification in so far as to classify the Tupaioids within the Primate order; yet in another part of the same work placental structure is used as an argument in favour of assessing affinities among Primate groups, *e.g.* separation of Tarsioids from Lemurs; impossibility of diphyletic origin of Platyrrhines and Catarrhines. If the placenta is to be used as a criterion at all it should be used consistently. Probably when more is known about its development and structure in a greater series of primitive Primate genera, more evidence for assessing affinities will be available.

This is still more true of the early stages of development of the ovum. Before the true relationship of the Lorisoids and Lemuroids can be defined on embryological information, it is necessary that true Lemurs be studied as carefully as Hill has dealt with *Loris*, and meantime, it is perhaps premature to assume that the conditions in *Loris* and *Nycticebus* are to be taken as representing a " Lemuroid " stage in the evolution of the foetal membranes of higher Primates.

DISCUSSION

Taking all the anatomical facts into consideration, it is evident that the several genera that have been classed together under the title of Lorisoids have sufficient in common to be so linked, and also that this community of characters is sufficient for separating them taxonomically from all the remaining members of the old suborder Lemuroidea. This much has been acknowledged in all the more recent attempts at Primate classification. But practically all these attempts restrict themselves to the division of the suborder into two lesser series labelled as *Lorisiformes* and *Lemuriformes*. It is true that on the one hand the lorisiform galagos approach the *Lemuriformes* in some of their characters; and that, on the contrary, the Madagascar Cheirogaleinae have certain features otherwise occurring only in *Lorisiformes*, yet these discrepancies are not considered sufficient in themselves for separating galagos from alliance with the lorises and pottos, or for uniting the cheirogales therewith. It seems that the Lorisoids, although specialized along lines of their own in certain ways, are yet in the sum-total of their characters definitely more primitive than the Lemurs, but that among the latter the mouse-lemurs (Cheirogaleinae) are to be considered the most primitive, and therefore

approaching the Lorisoids the more closely. Of the Lorisoids, the galagos are considered the most highly evolved, and the most distant from the basal Lorisoid stock. Their evolutionary trends have been such as to lead them to possess some characters parallel with those of Lemurs. With these preliminary remarks the anatomical characters of the Lorisoids may be analysed and compared with those of the Lemuroids and the Tarsioids.

The Lorisoids as a group have been shown to possess a strange medley of characters; some generalized; some specialized; some in common with Lemurs; some in common with Tarsioids and some different from both.

In the first place perhaps it is best to enumerate the characters in which the Lorisoids differ materially from the Lemurs. These are:—

1. Form and ribbing of external ear
2. Reduction of vibrissae
3. Absence of special skin glands on fore-limb
4. Reduction of digits II and III
5. Globular skull with shortened face
6. Enlargement of orbits
7. Os planum in orbit
8. Ethmo-maxillary fissure
9. Lachrymal on orbital margin
10. Infraorbital canal single
11. Maxillo-turbinal covered by foremost ethmo-turbinal
12. Structure of tympanic region and related foramina
13. Increase in presacral vertebrae (except *Galago*)
14. Shape of gluteal fossa on ilium
15. Reduction of tail (except *Galago*; occurs also in *Indris*)
16. Lack of disproportion between limbs (except *Galago*)
17. Elongation of tarsus
18. Microstructure of tooth-enamel
19. Tendency to disappearance of upper lateral incisors
20. Tendency to quadricuspidate upper molars
21. Cuspidation of margins of talonid basin on lower molars
22. Vallate papillae on tongue form a triangle
23. Absence of lateral organs on tongue
24. Increase of conical papillae from base to apex of tongue
25. Different shape of sublingua
26. Globular stomach
27. Spiral twisting of colonic loop (except *Loris*)
28. Lessened tendency to multilobulation of liver
29. Incompleteness of tracheal rings
30. Special form of renal papilla
31. Unilobular prostate
32. Smooth glans penis (except *Galago*)
33. Complete perforation of clitoris by urethra

34. Two pairs of mammae (also in *Cheiromys*)
35. Broader aortic arch
36. Mode of termination of eutocarotid artery
37. Retia mirabilia
38. Single head to biceps flexor brachii (except *Galago*)
39. Hypertrophy of visual apparatus and alteration of visual axes

On the contrary the Lorisoids agree with the Lemurs in the following important characters : —

1. Woolly coat
2. Strepsirhine rhinarium
3. General form of manus and pes and digital formula
4. Non-closure of orbit from temporal fossa
5. Reduction of premaxillae
6. Form of hyoid bone
7. Structure of carpus (in part)
8. Reduction of upper incisors
9. Modifications of lower incisors and canines
10. Presence of sublingua
11. Free duodenum
12. Colonic loop
13. Os penis
14. Structure of spermatozoa
15. Bicornuate uterus, each cornu opening separately into vagina
16. Nocturnal type of retina, with absence of macula
17. Placentation diffuse and epithelio-chorial

Lorisoids are distinguished from the Tarsioids by the following characters : —

1. Strepsirhine rhinarium
2. Form of manus and pes, and reduction of digits II and III
3. Non-closure of orbit from temporal fossa
4. Arrangement of turbinate bones
5. Increase in presacral vertebrae
6. Absence of tubular external auditory meatus (incipient in *Loris*)
7. Outer pterygoid lamina does not extend back on to side of bulla
8. Separation of tibia from fibula
9. Dental formula
10. Presence of os penis
11. Separate openings for vas deferens and ducts of seminal vesicles
12. Complete perforation of clitoris by urethra
13. Placentation diffuse and epithelio-chorial

In analysing these lists of characters, it is essential to bear in mind that all of them have not the same value in adjudicating on the affinities of the forms concerned. Some of the characters are purely adaptive, *e.g.*, many of the features of the galagos, especially those in which they differ from the other Lorisoids and approach the Lemurs. It is

necessary therefore to pick out those characters which are basic Lorisoid properties and to compare these with similar Lemuroid and Tarsioid characters.

The enumeration of the characters in which Lorisoids differ from Lemuroids forms a striking list when compared with those in which they agree. Further, the characters in which Lorisoids differ from Lemuroids are in the majority of items precisely those in which they resemble Tarsioids. Thus, in the first table items, 1, 2, 3, 5, 6, 7, 12, 14, 17, 18, 23, 29, 30, 31, 32, 34, 35, 36, and 39 are definitely Tarsioid characters, and in addition some of these are characters present in monkeys also, e.g., items 2, 3, 5, and 7. The enamel structure is common to Lorisoids, Tarsioids, and Platyrrhine monkeys. Of the remaining characters in list 1 many are to be regarded as Lorisoid specializations, i.e., characters which Lorisoids have evolved on their own account, thus departing from all other lower Primates. Among these come items 4, 8, 10, 11, 13, 15, 19, 25, 26, 27, 33, 37, and 38. A goodly number of the characters in the first list are primitive features retained by Lorisoids but lost by Lemuroids. Among these are numbers 3, 16, 31, 32, and 34. At the same time Lorisoids have escaped several Lemuroid specializations such as the extreme specialization of the carpus, the great length of the hind limb over the fore limb, duplication of the infraorbital foramen, completeness of tracheal rings, armature of glans penis, etc.

Difficulties arise, however, when the second list is analysed. Here Lorisoids are found to agree in a number of features with the Lemuroids and some of these features are generally regarded as Lemuroid specializations, e.g., items 3, 5, 6, 7, 9, 10. These characters occuring in Lorisoids, despite the long separation of the two series in geological time, have been explained, I think correctly, by Le Gros Clark as due to the recent mainfestation of evolutionary tendencies present, but latent, in the ancestors of both Lemuroids and Lorisoids. On the other hand the common possession by both groups of such characters as the strepsirhine rhinarium, non-closure of orbit posteriorly, os penis, bicornuate uterus and diffuse epithelio-chorial placentation is to be explained as retention by both of primitive mammalian features from their ancestors among the basal Primate stock of the early Eocene.

The galagos form a further difficulty by their possession of characters otherwise found only in true Lemurs. There is no doubt that the galagos are furthest removed from the Lorisoid type, although exhibiting undoubted Lorisoid features in the sum-total of their anatomy. Their departures from the Lorisoid pattern invariably occur in the

direction of Lemuroid characters, e g., long tail, great length of hind limbs, less modified molar teeth, grappling spurs on glans penis, double head to biceps. Their hind limbs and lengthened tarsal regions are also paralleled by *Tarsius*, and to a less degree in fossil Tarsioids. Undoubtedly these spec alization of the galagos have some connection with their more active habits and their saltatory mode of progression. Lemuroid characters are to be explained as due to parallel evolution implanted on a substratum which is definitely Lorisoid in general plan. The only character which it is difficult to explain in this way is the glans penis. No satisfactory explanation of the occurrence of this in galagos is yet forthcoming.

In the Cheirogaleinae we have the antithesis of the galagos. Here definite Lorisoid traits are implanted on top of a general anatomical complex which is decidedly Lemuroid, but lacking many of the more advanced Lemuroid characters. Lorisoid characters present in Cheirogales are mainly primitive ones and affect such organs as the tongue and glans penis. The state of the tympanic region and its associated vessels is difficult to explain in this way, but in the absence of any other explanation this view must be accepted tentatively. The Cheirogaleinae do not resemble the Lorisoids sufficiently to be classified therewith, and their habitat being Madagascar revolts against such an action. There is no doubt that the statement of Le Gros Clark, that the subfamily is to be regarded as the most generalized of the living lemuriforms, is correct.

CONCLUSIONS

The above discussion leads us to the following main conclusions :—

1. The Lorisoids are separated from the Madagascar Lemurs by numerous anatomical characters.

2. Most of the characters distinguishing them they hold in common with Tarsioids, to which therefore they are more closely allied than to the Lemurs.

3. The characters which Lorisoids have in common with Lemurs are due either to retention by both groups of primitive mammalian traits or to parallel evolution, i.e., to the manifestation in both series of characters latent in their ancestors though already present in the germplasm as an evolutionary trend.

4. The apparent departures of the galagos from the Lorisoid type in a Lemuroid direction are to be explained as due to adaptation to a particular mode of life and consequent parallel evolution.

5. The anatomical apartness of the Lorisoids should receive more attention than at present in schemes of Primate classification. If the Primate order is to be separated primarily on characters of the rhinarium, then Lorisoids fall in with the Lemurs as part of the strepsirhine suborder; but within this suborder they should hold rank at least equivalent to the Tarsioids in the haplorhine suborder. Personally it seems preferable to treat Tarsioids, Lorisoids, and Lemuroids as suborders so that Primates should be classified thus:

Order PRIMATES

Suborder I ANTHROPOIDEA
Families *Hominidae, Australopithecidae, Simiidae, Hylobatidae*

A.Haplorhine series
Suborder II PITHECOIDEA
A. Series *Catarrhini*
Families *Cercopithecidae, Parapithecidae*
B Series *Platyrrhini*
Families *Cebidae, Hapalidae*
Suborder III TARSIOIDEA
Families *Tarsiidae, Necrolemuridae*

B.Strepsirhine series
Suborder IV LORISOIDEA
Families *Galagidae* (*Galago* and *Euoticus*) and *Lorisidae* (*Loris, Nycticebus, Perodicticus* and *Arctocebus*)
Suborder V LEMUROIDEA
Families *Lemuridae, Indriidae, Archaeolemuridae, Adapidae, Megaladapidae, Notharctidae*
? Suborder VI CHEIROMYOIDEA
Families *Cheiromyidae, Plesiadapidae*
? Suborder VII CAECILIOLEMUROIDEA
Family *Caeciliolemuridae*

The above arrangement of the Primates is more in accordance with present day conceptions of the genealogy of the different groups, but

does not imply that any one group is ancestral to another. Before this can be done a better knowledge of fossil forms is requisite, more especially the discovery of fossils having undoubted Lorisoid traits.

I wish to acknowledge the help I have derived in writing this paper from conversations I have had with Professor J. P. Hill, F.R.S. and Dr. C. Tate Regan, F.R.S.

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Survey of the Distribution of Mammals in Ceylon

BY

W. W. A. PHILLIPS, F.Z.S., M.B.O.U.

REPORT No. 12

Collection	...	... No. 14
Locality	...	... Cheddikulam, Northern Province.
Altitude	...	... 180 ft.
Date	...	... July 23rd and 24th, 1933.
Collector	...	... Mr. E. C. Fernando, Taxidermist, Colombo Museum.

Mr. E. C. Fernando, of the Colombo Museum, visited Cheddikulam in July, 1933, and brought back a few bats that he was able to shoot on two successive evenings. As no previous collection from the Northern Province had been examined, this small collection is of interest. It extends the known range of several species.

Cheddikulam lies in the Mannar District of the Northern Province. It is a small village on the railway and is surrounded by thick scrub jungle. The country is flat and low-lying and is of the usual northern dry-zone type. The annual rainfall averages approximately 50 inches, most of which falls during the north-east monsoon period. Most of the bats were shot when flying over the railway line or over a paddy field. Mr. Fernando informs me that he believes that the Long-armed Bats came out of the coconut palms growing in the village and the Wroughton's Bats from a pile of high rocks a few miles distant.

(No. 20) **Pipistrellus coromandra** (Gray)

The Coromandel Pipistrel

1 ♂ and 1 ♀ in formalin. Both typical.

' Shot flying over '. A common species which appears to be resident throughout the dry zone. (*See also Reports Nos. 2, 6, and 9.*)

(No. 29) **Hesperoptenus tickelli** (Blyth)

Tickell's Bat

1♂ and 1♀ in formalin. Both typical.

' Shot flying over '. A very common species throughout the whole of the low-country, both in the dry zone and in the wet, and is found also in the hills, to an altitude of about 2,500 feet. A slow-flying species that occurs in most collections of bats. *(See also Reports Nos. 2, 3, 5, 6, and 9.)*

(No. 24) **Scotophilus wroughtoni** Thomas

Wroughton's Bat

6 ♂♂ s and 1♀. Skins and Skulls.

' Shot flying over '. A very useful series of a species of which there are but few specimens in the Museum collection. It now appears that this bat, which has hitherto been regarded as rather a rare species in Ceylon, is, at certain seasons, very numerous around the tanks in the dry zone. In addition to the present specimens, four were shot and literally hundreds were seen flying over a small half-dry tank near Trincomalee during July, 1934. As soon as the dry zone tanks commence to dry up, multitudes of flies appear on the rotting vegetation and each evening hundreds of bats, of the present and other species, congregate to feed upon them. In the present specimens, there is a distinct yellowish suffusion in the fur; this I have previously noticed on other specimens of this species taken in Ceylon. *(See also Reports Nos. 2 and 9.)*   •

(No. 28) **Taphozous longimanus** Hardwicke

The Long-armed Sheath-tailed Bat

1♀ Skin and Skull.

' Shot flying over '. A large female in the dark grey pelage of the youngish adult. The membranes are, however, unusually dark for this species, and are uniform dusky, blackish-brown, approaching in depth of colour to those of *Saccolaimus*. Previously, this species had not been recorded from the Northern Province; probably, however, it occurs throughout the low-country, in both wet and dry zones. *(See also Reports Nos. 8 and 9.)*

(No. 30) **Saccolaimus saccolaimus** (Temminck)

The Pouch-bearing Sheath-tailed Bat

1 ♀ in formalin. Typical.

' Shot flying over '. A common species, well distributed throughout the low-country and lower hills, but not previously recorded from the Northern Province. (See also Report No. 8.)

As one or two specimens of Monkeys were required for purposes of examination and comparison, a taxidermist was sent to Cheddikulam, again, early in October, 1933. He obtained five good specimens, two Macaques and three Grey Langurs.

(No. 1) **Macaca sinica sinica** (Linnaeus)

The Ceylon Toque Monkey

Macaca sinica inaurea Pocock 1931. *Jour. Bombay Nat. Hist. Soc.* Vol. XXXV, p. 286.

2 ♂♂ s. Both good specimens, complete with skulls.

These two specimens are from the type locality of the race *inaurea* described by R. I. Pocock in the *Journal of the Bombay Natural History Society* (Vol. XXXV, p. 286). Pocock was, however, working upon material collected over fifteen years earlier and lodged in the British Museum collections and it is obvious to anyone acquainted with the Ceylon Macaques in life that the faded condition of this material led him into several errors. The present skins are both of adult males. In both, the general colour of the dorsal aspect is dusky chestnut or reddish-brown, the colour brightening to a rather more golden tint on the shoulders and on the thighs. The individual hairs are dusky blackish-brown for some two-thirds of their length, with long chestnut or reddish-brown tips. Pocock, in his very meagre description of the type of his *inaurea*, merely states ' distinguished by the absence of red from the pelage, apart from the outside of the thighs, the general hue of the head, shoulders, back and arms being yellowish olive, the hairs being merely annulated with greyish buff '. This description is not only totally inadequate, but is obviously taken from a faded skin or skins and is therefore useless to distinguish a new form from the typical race.

To those who understand the distribution of the climatic zones in Ceylon, it appears most unlikely that a second race of macaques could exist in the same zone, under the self-same climatic conditions,

as the typical race *sinica*, for which Pocock has fixed upon the Maha-
oya district as the type locality. If therefore, we admit the dry zone
as the type locality of the typical race, *sinica*, then *inaurea* must be
considered a synonym of the typical race, from which it appears to be
indistinguishable.

(No. 2) Pithecus entellus thersites (Blyth)

The Ceylon Langur

1 ♀ , 2 ♀ ♀ . Juveniles.

These three specimens form a welcome addition to the Colombo
Museum collection, in which the species is poorly represented. The
adult female is unusually dark in colour.

Collection	No. 15
Locality	Katagamuwa Distr ct, Southern (Pala-tupana) Resident Sportsmens' Reserve, Southern Province.
Altitude	Approx. 50 feet.
Date	September 2nd to 6th, 1933.
Collected by	Mr. E. C. Fernando, Taxidermist, Colombo Museum.

(See also Reports Nos. 3 and 6.)

Early in September, 1933, Mr. E. C. Fernando accompanied Dr. L.
Nicholls on a short trip into the northern area of the Southern Resi-
dent Sportsmens' Reserve. Although the collecting of small mammals
was not the main. object of the trip, Mr. Fernando was able to trap
a few small rodents and to collect one or two other specimens which
form a useful supplement to previous collections made in the same
area. Katagamuwa lies between Galge and Yala in both of which
localities collections had previously been made. Its main feature
is a large, ancient, artificial lake or ' tank ' which supplies water to
much of the larger fauna of that part of the Game Reserve.

For a detailed description of the country and of previous collections
made therein, see Reports Nos. 3 and 6 of this series.

(No. 17) Megaderma spasma ceylonense Andersen

The Ceylon Vampire Bat

1 ♂ . Typical.

This single specimen, of the commoner of the two Ceylon vampires,
greatly increases the known range of the race. Hitherto no vampire

had been recorded from the south-eastern districts. It would now seem probable, however, that this species is found throughout the low-country of the whole Island. The present specimen had on it several Polyctenid bugs. (*See also Reports Nos. 2 and 7.*)

(No. 44) Felis rubiginosa Belanger

The Rusty Spotted Cat

1 ♀. Typical.

' Shot at night '. A very nice specimen of this beautiful little wild cat. This species appears to be common throughout this area. The scrub jungle is very attractive to it and small rodents and ground birds are numerous. (*See also Report No. 11.*)

(No. 65A) Ratufa macroura sinhala Phillips

The Common Ceylon Giant Squirrel

1 ♀ Sub-adult.

A very useful specimen showing well the light isabelline colour of the juvenile of this race. It is in perfect coat and is considerably lighter than the typical adult. (*See also Report Nos. 3, 5, 7, and 11.*)

(No. 67) Funambulus palmarum kelaarti (Layard)

The Lowland Ceylon Palm Squirrel

2 ♀♀ s, one sub-adult.

Both these specimens are typical *kelaarti*, which is the race one would expect to find in this area. They are quite different in colour to the six specimens, obtained earlier in the year, from Galge (see Report No. 9) 25 miles further north, and also to the single specimen obtained by Mr. A. C. Tutein-Nolthenius from near Yala, a few miles to the south-east. The palm-squirrels of this area are very puzzling and many more specimens, collected on various dates throughout the year, are required before the changes in the colour of the pelage can be satisfactorily followed and the race to which many of them belong, determined with real certainty. (*See also Report No. 11.*)

(No. 78) **Tatera ceylonica** Wroughton

The Ceylon Gerbil or Antelope Rat

2 ♂♂ s,1 ♀. in alcohol. All typical.

Three small specimens of the commonest rodent of the dry-zone area. Gerbils are very common throughout the whole district. (*See also Report Nos. 3, 4, 9, and 10.*)

(No. 79) **Millardia meltada meltada** (Gray)

The Soft-furred Field Rat

1 ♀. Skin and skull.
2 ♂♂ s, 2 ♀♀s (one juvenile) in alcohol } All typical.

This species has occurred in all the previous collections from this area. It seems to be a common species in the drier areas of the Southern and Uva Provinces and is probably common throughout the greater part of the dry zone. The young is like the adult, except that its fur is relatively longer and more fluffy. (*See also Report Nos. 3 and 6.*)

(No. 79A) **Leggadilla fernandoni** Phillips

The Ceylon Spiny Mouse

3 ♂♂s, and 1 ♀ skins and skulls, 1 ♂ and 4 ♀♀s in alcohol.

A fine series of good specimens and a very welcome addition to the Museum collection. Hitherto, this spiny mouse has been considered to be rather rare, but it now appears to be quite common and well distributed in this area of the Southern Province. As noted previously, the old males are a lighter fawn than the younger males and the females. (*See also Reports Nos. 2, 6, and 9.*)

Collection	No. 16.
Locality	Kumana (Bagura) District in the Panama Pattu, Eastern Province.
Altitude	Approx. 10 to 50 feet above sea level.
Date	November 25th to December 9th, 1933.
Collected by	A. C. Tutein-Nolthen·us and Museum Collectors.

The Kumana District lies to the immediate north-east of the Yala Game Sanctuary, the boundary between them being the Kumbukkan oya. The country is very much the same as that lying to the south-west of the Sanctuary and described in Report No. 3. It is, for the

most part a flat, sandy, scrub-covered plain with numerous grassy glades or open parks and one or two rocky outcrops. At Bagura there is an extensive open plain and a large lagoon while some two miles from Kumana village there is an old tank, lately repaired. With the exception of a few villagers living at Kumana the country is practically uninhabited. Larger animals, such as elephants, buffaloes, deer, leopards, and bears are numerous throughout the area and many large storks and other waders nest on trees in the Kumana lagoon. The annual rainfall averages about 55 inches, almost all of which falls during the north-east monsoon period, the country being dry and parched during the greater part of the year.

At the time of Mr. Tutein-Nolthenius' visit, heavy rain was falling and the country was flooded in places. He experienced difficulties in moving from place to place and in his collecting work. Traps, baited with coconut or scraps of meat, were set each night, but many of these were robbed by carnivorous animals and some were entirely removed. Mr. A. C. Tutein-Nolthenius has set an excellent example by combining his shooting and inspection trips with most useful collecting work and it is hoped that other sportsmen will follow his example.

Although there is nothing new in the present collection, many of the specimens obtained are of much value and interest.

(No. 14) **Hipposideros speoris speoris** (Schneider)

Syke's Leaf-nosed Bat

1 ♂ Sub-adult. Itchigala; Hehigala; Bagura.

' Caught in a cave '. The commonest of the Rhinolophidae in Ceylon and well distributed throughout the lowlands and lower hills. (*See also Report Nos. 2 and 10.*)

(No. 32B) **Suncus caeruleus caeruleus** (Kerr)

The Common Indian Music Shrew

1 ♀. Kumana wewa.

A very useful specimen with, unfortunately, a damaged skull. The typical race of this shrew is uncommon in Ceylon, and is, as far as our knowledge goes, confined to the dry zone. (*See also Report No. 10.*)

(No. 56) **Herpestes smithii zeylanicus** Thomas

The Ceylon Ruddy Mongoose

1 ♀ Typical. Bagura Kalapane.

' Shot on the plain; had a ¾ grown youngster with it. Saw a few more of the same species '. A good specimen in excellent coat. The skull is, unfortunately, damaged. This species is the commonest mongoose of the southern and eastern dry zone jungle tracts. (*See also Report No. 10.*)

(No. 66) **Funambulus palmarum** sub sp.

The Ceylon Palm Squirrel

1 ♂, 1 ♀. Mudam kulam, Pagura. 1 ♀ Sub-adult. Bagura kalupuwa. 2 ♂ Kumana wewa.

As regards these five specimens, I can only repeat the remarks made in Report No. 11 relative to the specimens of the palm squirrels collected at Galge (Uva). The palm squirrels of this part of the Island and the south-easterly districts generally, are most puzzling. In all the present specimens, the median stripe is white and the two outer are buff. One has a distinct reddish cap while the remainder have a slight reddish suffusion only. More specimens are required, taken at other times of the year, from this part of the Island before the race to which they belong can be determined with any certainty. (*See also Report No. 11 and the present Report.*)

(No. 73) **Tatera ceylonica** Wroughton

The Ceylon Gerbil

5 ♀♀s. Helawa wewa. 1♂,3 ♀♀s. Bagura kalupuwa. 5 ♀♀s.⎫ All typical.
(one sub-adult) Mudam kulam, Bagura   ⎭

These fourteen specimens form a very fine series which will be most useful for future work. The Gerbil is the commonest rodent in the dry-zone jungles and probably forms the chief food of the smaller carnivora. (*See also Reports Nos. 3, 4, 9, 10, and the present.*)

(No. 76) Rattus rattus kandiyanus (Kelaart)

The Common Ceylon House Rat

2 ♂♂s, 2 ♀♀s. Kumana wewa. 1♂(sub-adult), 2♀♀(one ⎤ All typical.
sub-adult) Mudan kulam, Bagura. 1 ♀Helawe wewa   ⎦

These eight specimens are typically white-bellied jungle rats. In all, the white belly hairs are unicoloured throughout, with no grey at the base. The upper parts are very rufescent. (*See also Reports Nos. 2, 7, 10, and 11.*)

(No. 78) Rattus blanfordi (Thomas)

The White-tailed Rat

1♀. Helawe wewa.

An excellent specimen and a very useful addition to the Museum collections. This specimen is rather darker in the colour of the upper parts and has softer fur than the other specimens examined. It is evidently not a common species but appears to be well distributed through the dry-zone jungles of the Eastern and Uva Provinces. (*See also Reports Nos. 7 and 11.*)

(No. 79) Millardia meltada meltada (Gray)

The Soft-furred Rat

3♂♂s (one sub-adult), 2♀♀s. Mudan kulam, Bagura.⎤ All typical.
1♂. Bagura kalupuwa   ⎦

An interesting and useful series. This field rat would appear to be common throughout the whole of the south-eastern area and very possibly throughout the entire area of the dry zone. (*See also Reports Nos. 3, 6, and the present.*)

(No. 81) Leggada booduga fulvidiventris (Blyth)

The Ceylon Field Mouse

1♂, 1♀. Mudam kulam, Bagura. Typical.

This little mouse does not seem to be so common in this district as one would expect and it is remarkable that it has not been taken in any localities where the Spiny-mouse (*Leggadilla fernandoni*) has been obtained. The present specimens will be useful for comparison with specimens from the wet zone. (*See also Reports Nos. 2, 4, and 10.*)

(No. 86) **Golunda ellioti coffaea** Kelaart

The Coffee Rat or Ceylon Bush-rat

1 ♀ (sub-adult) Kumana wewa.

It is interesting to see a specimen of the Golunda from this part of the Island. The occurence of the species in this area was suspected but no specimen had previously been secured. The present specimen is both darker in general hue and less spinous in its dorsal fur than other dry-zone specimens but this is probably due to its youth. It does not appear to be at all common in the dry zone, though it is evidently well distributed. Further specimens are badly wanted. (*See also Reports Nos. 2 and 8.*)

(No. 88) **Lepus nigricollis sinhala** Wroughton

The Ceylon Black-naped Hare

1 ♂. Bagura. Typical.

' Weight 3 lb. '. Hares are common throughout this district and the lowlands generally.

.   .   .   .

Mr. Tutein-Nolthenius has very kindly supplied the following notes on some of the larger animals seen during his trip.

(No. 42) **Panthera pardus fusca** (Meyer)

The Indian Leopard

One seen. Some tracks of a very large animal seen near the sea coast at Bagura.

(No. 58) **Canis lanka** Wroughton

The Ceylon Jackal

Several seen, large and in fine condition. Some of them played, just in front of our camp, with a pariah dog that had followed us from Kumana.

(No. 60) **Melursus ursinus** (Shaw)

The Indian Sloth Bear

None seen but we heard three and saw fresh tracks.

(No. 89) **Bubalis bubalis bubalis** (Linné)

The Wild Buffalo

Every plain had a few bulls on it and there were several small herds at Bagura, all in fine condition, but no very good heads. All were rather shy at the sight of man.

(No. 91) **Axis axis ceylonensis** Fitz

The Ceylon Spotted Deer

Small herds were on most of the large plains but they were not as numerous as one would expect. All were in good condition, but no fawns were seen. Two stags had their antlers in velvet. One stag with antlers of about 30 inches in length, was observed covering a hind.

(No. 93) **Rusa unicolor unicolor** (Kerr)

The Sambhur

A few seen. A fine stag, with antlers of 27 inches in length, was seen near the seashore.

(No. 94) **Moschiola meminna** (Erxl.)

The Mouse-deer

One seen and several tracks noticed.

(No. 95) **Sus cristatus cristatus** Wagner

The Indian Wild Pig

A small number seen, several of them fine large boars. The tushes of one exceptionally large boar could be seen with the naked eye, at a distance. No young were observed.

(No. 96) **Elephas maximus zeylanicus** Blain

The Ceylon Elephant

Observed a herd of eight, led by a very large cow that had recently given birth to a calf. This calf was the smallest ever seen by us and appeared to be not more than nine or ten days old. It walked between its mother's hind legs and then sat down on its tail, like a spaniel

would. Other animals in the herd were from about 3 feet up to
about 8 feet in height. A few more elephants were both seen and
heard but there did not seem to be very many in the neighbourhood at
the time of our visit.

REPORT No. 13.

Collection	No. 17.
Locality	Kankesanturai and the Jaffna Peninsula, Northern Province.
Altitude	15 feet.
Date	December 22nd/26th 1934.
Collector	W. W. A. Phillips and Collector William Perera.

This small collection was made during a short Christmas holiday,
spent at Kankesanturai within a few miles of Point Pedro, the most
northern point of the Island. Previously, no collecting work had
been done in the Jaffna Peninsula, although collections had been made
at Mannar, Marichchukaddi and Cheddikulam (see Reports Nos. 10 and
11 of this series) some 70 miles to the southward.

The Jaffna Peninsula, which forms the extreme northern extension
of Ceylon, is practically an Island and is joined to the mainland only by a
causeway at Elephant Pass, over which the railway and the road run
side-by-side. The country is very flat and low lying, being rarely more
than fifteen feet above sea level. Most of it is under cultivation,
mainly in the form of coconut and palmyrah palm groves, paddy fields
and tobacco and vegetable gardens, but where the soil is very shallow
there are tracts of scrub and grazing ground, while along the east
coast there is a long, narrow strip of sand-dune country running the
whole length of the Peninsula. The population is relatively dense,
and is chiefly composed of Jaffna Tamils, an industrious and thrifty
race.

Owing to the Miocene limestone deposits, closely underlying the
soil, the vegetation is luxuriant during the months when sufficient rain
falls; but as the Peninsula lies within almost the driest portion of
the Island, it is usually only from October to December, during the
north-east monsoon period, that any appreciable amount of rain is
received. During the remaining nine months of the year, the country
is dry and parched and there is little cover for small mammals, except
in the hedges and rough stone walls that divide the fields and gardens.
The average rainfall is only about 47 inches.

The mammalian fauna appears to be closely akin to that of the
neighbouring Indian coastal region—the Coromandel coast—distant

some 20 miles to the west. Nothing of very great interest has come to light in the present collection, but the known range of several species has been greatly increased.

In the making of this collection, I received assistance from Mr. P. Mudaliyar Jegarajasingham of Sandilipay, to whom my best thanks are due. Mr. Jegarajasingham has very kindly undertaken to make a supplementary collection of bats and small mammals, which collection is awaited with interest.

(No. 2) **Pithecus entellus thersites** (Blyth)

The Ceylon Langur

I was pleased to see a small troop of these monkeys on the road, not far from Pallai. They were quite tame and evidently had but little fear of man. Several of the females were carrying small youngsters. Jaffna Tamil name = Mundi Kurangu.

(No. 18) **Lyroderma lyra lyra** (Geoffroy)

The Indian Vampire Bat

1 ♂. Keerimalai.

Mr. Jegarajasingham procured one of these large bats for me. It was knocked down, at night, in a house. I saw several by the light of my car headlights, flying about the roads, and believe that the species is fairly common in the Peninsula. Jaffna Tamil name = Vaval.

(No. 20) **Pipistrellus coromandra** (Gray)

The Coromandal Pipistrel

2 ♀. Kankesanturai.

Shot in the evening. A common species throughout the Peninsula. Jaffna Tamil name = Mampala vaval (Mango bat).

(No. 24) **Scotophilus wroughtoni** Thomas

Wroughton's Bat

1 ♀. Nr. Kankesanturai. ♂ 1, ♀ 2 Aralie, Nr. Jaffna.

Shot in the evening. A very common species, in the more open places. Generally flies about 20 feet above the ground level. Jaffna Tamil name = Mampala vaval (Mango bat).

Several species of Leaf-nosed Bats were seen but none were captured or shot.

(No. 49) Herpestes lanka (Wroughton)

The Common Ceylon Mongoose

1 ♂.   Nr. Kankesanturai.

A large male, weighing 2¾ lb., was shot one evening in a young palmyrah grove.   Mongooses, of two species were reported to be fairly common throughout the wilder parts of the Peninsula.   Jaffna Tamil name = Keerie.

(No. 66) Funambulus palmarum brodiei (Blyth)

The Northern Ceylon Falm Squirrel

3 ♂, 2 ♀,   sub-adult ♂ 1, sub-adult, ♀ 1.   Kankesanturai.

Palm-squirrels of this race were extremely common throughout the Peninsula and a useful series was trapped at Kankesanturai.   Jaffna is the type locality of this race, so the present series should prove useful for comparative purposes.   Jaffna Tamil name = Anil.

(No. 78) Tatera ceylonica (Wroughton)

The Ceylon Gerbil or Antelope Rat

1 ♂, 1 ♀;   sub-adult, ♀ 1.   Nr. Kankesanturai.

The Gerbil appears to be common throughout the Peninsula and would, doubtless, be very much more so, were it not eaten commonly by the lower caste Tamils.   Burrows were observed in many places, even within the walls of the Dutch fort at Jaffna.   Jaffna Tamil name = Vell 'elli (White rat).

(No. 76A) Rattus rattus rufescens (Gray)

The Common Indian Rat

2 ♂, 3 ♀.   Kankesanturai.

The rats of this neighbourhood are a little puzzling—they are neither typical *rufescens* nor typical *kandiyanus*.   One male has a creamy belly and the other a grey, while two of the females have creamy bellies and the third a grey belly.   I think that they are most probably hybrids between the imported Indian race *rufescens* and the indigenous race *kandiyanus*, with the *rufescens* strain predominating.   Jaffna Tamil name = Veedtu 'ellie.

(No. 81) Leggada booduga fulvidiventris (Blyth)

The Ceylon Field Mouse

♀ 1. Near Kankesanturai.

A single female was trapped in a hedge on waste land, some 4 miles from Kankesanturai. It is quite typical. The species is reported as being rather uncommon in the Peninsula. Jaffna Tamil name = Sit 'elli or Sund 'elli.

Gunomys spp. Mole-rats are reported to be common in the paddy-fields. They are captured and eaten in large numbers by low caste villagers after the harvest. I was unable to procure a specimen as, at the time of my visit, the paddy was still growing. These mole-rats may be *G. gracilis*, the Ceylon mole-rat, but I suspect they will prove to be the Indian form, *G. kok*. Jaffna Tamil name = Nell 'elli (paddy rat) or Agillarne.

Suncus spp. Shrews, most probably the Indian Grey Shrew (*Suncus caeruleus caeruleus*) are reported to be fairly common but none were caught. Jaffna Tamil name = Munjuru.

NOTES

1. The Nesting habit of Leathery Turtle Dermochelys coriacea

The nesting habit of the Leathery turtle *Dermochelys coriacea* (Linné), does not appear to have been described by any zoologist who observed the process, for opportunities to study this animal are rare. Recently a female was discovered when she came ashore to lay. Previous observations have shown that the nesting season reaches its maximum intensity in Ceylon during May and June, after the beginning of the south-west monsoon [1]. Broad beaches of *fine* sand, devoid of fringing reef are preferred, and as many as seven or eight nest trails sometimes occur within one kilometre of beach. Examination of freshly made nests at night showed that the turtle usually came ashore between 9 and 11 P.M. and in the present instance the animal was observed at about 9.30 P.M.

Glistening silvery in the moonlight, the turtle ascended the beach in a straight line to the sandy embankment created by the scouring action of the waves. Through this obstacle she cut her path with simultaneous jerks of her powerful fore flippers and gained the dry sand. Here, she commenced what Sinhalese fishermen term a ' sand-bath ' flinging up a shower of sand over her back to a distance of about three metres by strong simultaneous jerks of her fore limbs. The upward direction of these movements differed from her usual shuffle. The turtle probably tested the density of the sand while ' sand bathing ' for each jerk of her fore flippers excavated hollows which were 16 to 26 cm. deep. Her course was zig-zag and she even doubled back upon her track searching for a suitable place in which to nest. Meanwhile she was completely coated with sand, except for her eyes, which were washed by a copious flow of tears. After a satisfactory place was found, she dispelled the loose sand with a few preliminary sweeps of the flippers; a shallow

[1] Deraniyagala, P. E. P. 1930—The Testudinata of Ceylon. *Ceylon J. Sci.* (B) XVI. pp. 43-88, pls. 7.

cavity was next hollowed out posteriorly with a side to side movement of her carapace, facilitated by the out-stretched hind limbs and cruro-caudal fold of skin. During this operation, her fore flippers sank into the sand and apparently acted as anchors, while a cushion-like mound of sand lay heaped behind each. After these preliminaries she excavated a smaller nest hole within the crater by working the hind limbs alter-nately, flinging the sand to a distance of 30 cm. or more as it was brought up. When the combined depth of the crater and the nest hole was about 100 cm. and she could no longer reach the bottom of the pit, she began to lay.

P. Deraniyagala del.

Fig. 1.   *Dermochelys laying* × $\frac{1}{10}$

Anchored by the fore limbs, the turtle sloped her body into the pit at an angle of about 35 degrees, protruded her cloaca, and then deposited the eggs in batches of two or three at a time, moving her head up and down as she strained. Her breathing was somewhat stertorous and a peculiar fishy odour was noticeable. Her eggs laid, she began to fill in the nest hole working the hind limbs alternately, each taking up a flipperful of sand which was gently placed upon the eggs [1].

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[1] Two types of eggs are laid by *Dermochelys*. Normal ones containing albumen and yolk and with a diameter of 50-54 mm. usually number from 90-110 and abnormal ones which contain only albumen and are either small or variable in shape; these number 10-30 and are the last to be laid. According to egg collectors *Dermochelys* lays fewer eggs than either *Lepidochelys* or *Eretmochelys*.

This was continued until the eggs were well covered, after which the sand was pushed in rapidly. Eventually, with her fore limbs still buried, the animal demolished the brink of the nest pit by swinging her outstretched hind quarters and tail rapidly from side to side, although the carapace was stationary. During this procedure, every time a hind flipper touched the ground, it flung the sand crosswise towards its fellow with a rapid scooping movement (Fig 2).

P. Deraniyagala del.

Fig. 2. *Dermochelys* swinging her hind quarters above nest ✕ 1/16

Although the turtle is said to be cautious in her approach to land, once oviposition commenced the animal was completely indifferent to the presence of man, noise or lights, and this indifference persisted even after she had covered up the eggs and had begun to churn up the beach all round the nest, in spite of blows (Fig. 3).

Fig. 8. *Dermochelys* showering sand with fore flippers × $\frac{1}{15}$

When the nest was nearly covered, she moved her front limbs for the first time since oviposition commenced. Both were jerked back simultaneously, showering sand over her back and into the pit, but without visibly altering her position. She worked the front and hind limbs in turn over five minute intervals, the former always with a simultaneous jerk, the latter generally alternately. Eventually she gyrated on her plastron upon the nest area and flung up great scoopfuls of sand with her fore flippers, occasionally employing her head to push down any ridges of sand created during this process. Throughout this phase the turtle did not appear to move from the nest and it was only by comparing the animal's position with a haversack I had laid down when first she commenced to dig, that it became apparent that she had moved quite two metres during ten minutes. At this stage I struck her a sharp blow on the head with a stick and sat upon her, but undeterred she continued to churn up the sand and worked shoreward instead of towards the sea.

After a time she doubled back on her tracks and slowly and laboriously repeated the process. Finally she decided that her duty was done, and it was certainly very thorough, for after she had gone, three of us dug for an hour with our hands but were unable to locate the eggs. The departing turtle no longer showered sand with her fore limbs, but wearily made for the sea stopping after every two or three shuffles, blowing most of the time. Gradually she recovered her energy

and rested only after every ten or fifteen shuffles. She approached the wave line and there paused. The breakers were rough on the night of May 29, 1934, at Tangalla (Southern Province). When the surf reached her, she allowed herself to be washed away into the waves without exerting herself. At her first attempt she failed to get past the breakers, but as the next wave rose she hugged the ground. escaped under the wave, and was gone.

The track of *Dermochelys* is of interest. In marine Thecophora the nest is generally at the bend of a V formed by the ingress and egress trails of the animal. In *Dermochelys* the track roughly resembles the three sides of a rectangle of which the middle one is a long churned up area of sand in.which the nest may be located anywhere. The marks left in the sand were as follows ·—each time the long fore flippers shifted forward their tips cut thin arcs in the sand, and as the animal jerked herself forward, each limb impressed a wide furrow with a ridge of earth heaped along its posterior margin. The push off with the hind limbs formed an inner row of shallower furrows. As in most marine Thecophora, the tip of the tail ploughed a thin median furrow in the sand. The majority of tracks showed the ingress and egress trails about six to twenty metres apart, while the churned up area was generally five to ten metres long and two or three wide. In this instance, however, the turtle returned to the sea by the ingress trail, though this seldom happens.

The nesting behaviour of *Dermochelys* appears to be very intelligent for a testudinate. Young specimens in captivity are, however, less educable than marine Thecophora, for they never seem to realize that the sides of their tank are solid and persistently swim into them, thereby injuring their flippers and snout, which never heal owing to this habit. Marine Thecophora, however, soon perceive the nature of their prison walls and such injuries seldom appear and rarely last long.

Allied to the automatic swimming habits of this turtle, is its action in continuing to churn up the sand after she had been struck, while the simultaneous jerks of the fore limbs [1] which act as if the animal were attempting to swim on land, suggests that its nesting behaviour is essentially a series of reflexes which are less controlled by intelligence than would at first appear to be the case. The sand bathing habit is probably similar and of thigmotropic origin, for it commences soon after the turtle reaches dry sand. This habit, or rather reaction, is of definite protective value to the slaty-black animal, which is soon

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[1] *Dermochelys* swims by simultaneous sweeps of both fore limbs. The hind limbs are chiefly employed as balancers but occasionally are placed edge to edge and flapped up and down.

coated with sand and rendered inconspicuous upon a moon lit beach. The same habit also effectually conceals the eggs, for the odour of the turtle is evenly imparted throughout the disturbed area and thus renders it more difficult for other animals to scent out the nest hole, or determine its position by inspection and judgment.

P. E. P. DERANIYAGALA.

2. A boa new to Ceylon.
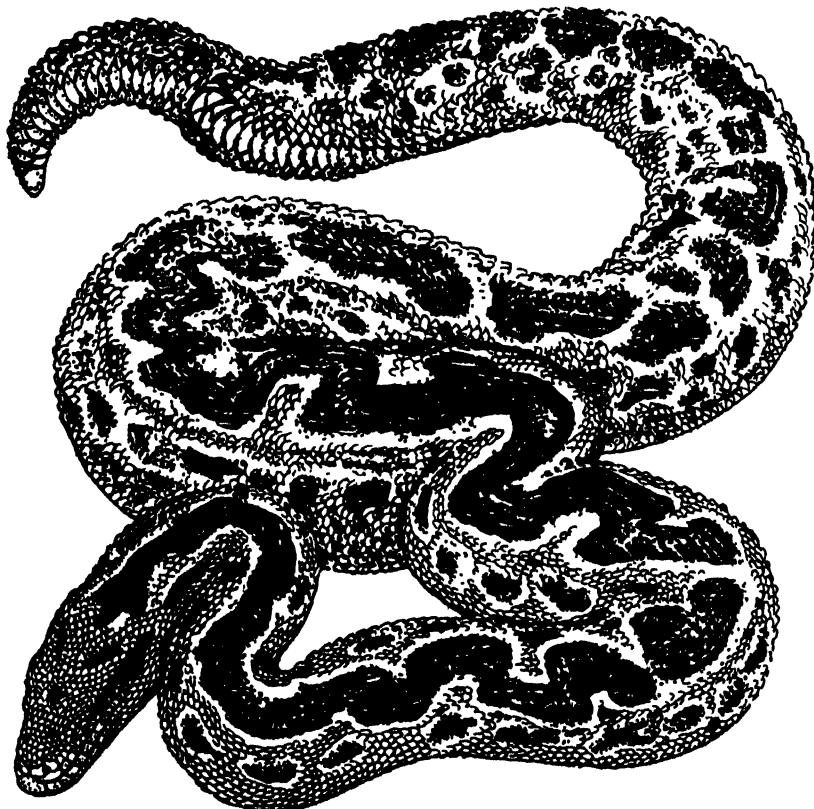
P. D. del.

Fig. 4. *Gongylophis conicus* × 1

The family Boidae was hitherto thought to be represented in Ceylon by a solitary species, *Python molurus* Linné. As a collection of reptiles from Marichchukadde, presented to me by G. Pillai, keeper of the Government Bungalow there, contained a solitary *Gongylophis conicus*

(Russell), it is very probable that this snake inhabits the arid northern part of Ceylon which also harbours several other South Indian reptiles which do not occur elsewhere on the Island. Pillai affirms that this snake is not uncommon during the rainy season which commences in October, that the Tamil name is *Munn pudeyen*, that the specimen collected is an adult, and was found in a termite hillock. Comparison with two specimens kindly lent by Dr. S. L. Hora of the Indian Museum, Calcutta, revealed that in the Ceylon specimen the pigmentation was more intense and differed in its cephalic markings, while certain minor features in its scales and teeth suggest that this form might eventually prove to be a new subspecies. The specimen has 190 ventrals and is 380 mm. long. It is deposited in the British Museum. Indian specimens attain to 650 mm.

<div align="right">P. E. P. DERANIYAGALA.</div>

3. Occurrence of Capella Megala Swinhoe, in Ceylon

From time to time various snipe-shooters in Ceylon have persistently asserted that one occasionally came across a snipe larger than the Pintail; but until recently I have never been able to verify these rumours. I had an idea that any large specimen obtained would prove to be either the Wood-snipe *C. nemoricola*, or the Solitary Snipe *C. solitaria*.

In April, 1934, however, Mr. R. H. Spencer Schrader of Negombo, kindly sent me a large snipe which he had shot on the 8th of that month at Maduramadu, a little tank near the road from Madawachchiya to Mannar.

It proved to be neither the Wood nor Solitary snipe, but a fine male specimen of Swinhoe's Snipe (*Capella megala* Swinhoe), a species which had not previously been recorded from Ceylon.

The general description, and the measurements usually taken for record, closely agreed with those of the common Pintail-snipe *C. stenura;* but in spite of the nearness of these measurements it was undoubtedly a considerably heavier bird, with a relatively larger body and rather stouter legs, while the white of the under parts extended forward on the chest rather further than in the average Pintail. The species may, however, always be distinguished by the tail feathers, which are constructed on a different formula.

The Pintail has usually twenty-six feathers in the tail. The eight or ten central feathers are more or less normally shaped. The remaining feathers on each side, the ' pin feathers ' are markedly narrow and stiff, the outermost feather being no broader than an actual pin.

In Swinhoe's Snipe there are never more than twenty feathers in the tail. The six central feathers are of normal shape; thereafter the successive feathers on each side diminish in breadth down to the outermost, which is very narrow, but not quite such an absolute pin as in the Pintail.

I give the measurements of the specimen sent me, they were recorded before the bird was skinned and placed in the Colombo Museum collection.

Length	283 mm.	=	11.16	inches.
Wing	138 mm.	=	5.44	,,
Tail	55 mm.	=	2.17	,.
Tarsus	32 mm.	=	1.26	.,
Bill from gape	63 mm.	=	2.48	,,

Soft parts. Bill brown at base, blackish at tip. Iris brown.

Legs and feet yellowish grey, claws blackish. Swinhoe's Snipe is a far-eastern form, breeding in E. Siberia, and N. China and migrating for the winter to S. China, the Philippines, Borneo, &c. The first specimen obtained in India was shot by Mr. E. C. Steuart Baker in 1906, in Lakhimpur. Since then this snipe has been recorded from various other localities in India, notably in 1912, when 6 specimens were shot at Chingleput, south of Madras. It is probable that occasional specimens visit the Island from time to time, but pass unrecognized owing to their resemblance to the Pintail snipe.

<div align="right">W. E. WAIT.</div>

4.　Birds of Mousakande Group, Gammaduwa, Central Province

Plates XXXII-XXXIV

Mousakande Group lies on the north-eastern aspect of the East Matale Hills. These hills form the northern extension of the Knuckles and Madulkelle range, a massif, rising to peaks of 6,000 feet, which is isolated by the valley of the Mahaweli-ganga, in its eastern course, from the main mountain cluster of the Central and Uva Provinces. The Estates forming the Group are located on steep hillsides, rising

from little more than 2,000 feet to over 4,000 feet on he highest ridges; they aggregate a total of some 1,800 acres. Much of this area is cultivated in tea but broad strips of jungle remain, forming wind-breaks, and the steeper slopes and higher peaks are still jungle covered. A few rocky outcrops and precipices occur in one or two places, while parts of the lowest estate are in rank grass or ' patana '. The climate is wet and windy during the major part of the year. The rainfall averages 130 inches, the greater quantity of which falls during the north-east monsoon. From about the middle of November to the second week in February, heavy rain mist and intermittent strong winds are usual, after which a period of sunny weather, with occasional heavy thunderstorms, generally follows until towards the end of May, or beginning of June, when the south-west monsoon is due. With the advent of this monsoon, the high winds commence and from then onwards until after the middle of August, the Group is very wind-swept and the sky is overcast with driven clouds. From the abating of the south-west monsoon to the onset of the north-east, the weather is again sunny and warm.

The effect of these climatic conditions upon the bird-life of the locality is most marked, many more birds being resident during the warm and sunny intermonsoon periods than are present while the monsoon winds are raging. The normal nesting season, for the majority of the resident species, is from March to May but should the weather conditions be favourable during August and September many species nest again.

The forests that surround the Estates are damp and leech-infested and are saturated with mist and rain water for many consecutive weeks. The undergrowth is rank except in those areas that have been planted with cardamoms, and the trees are tall except on the exposed wind-swept ridges where they have been stunted by the force of the winds. Cover and food, the two essentials to bird life, are in abundance in these jungles and the wealth of wild life that finds sanctuary in them is remarkable.

The following notes have been compiled during a residence on the Group of over six years, during which time the opportunities to study the wild life have been almost continuous.

1. *Corvus levaillanti culminatus*, the Black Crow [1]—An occasional and unwelcome visitor during the intermonsoon periods. During monsoon periods the winds are sufficient to keep it away. A breeding resident below Gammaduwa.

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[1] The numbers and names given in this paper, correspond with those given in the *Manual of the Birds of Ceylon* (Second Edition) by W. E. Wait, C.M.G.

4. *Parus major mahrattarum*, the Southern Grey Tit.—Resident but not in large numbers. A nest (c/4) was found on May 11th.

5. *Sitta frontalis frontalis*, the Velvet-fronted Blue Nuthatch.—A common resident in the upper part of the Estate and the surrounding jungles. The nest is difficult to discover but is sometimes in old holes excavated by the Yellow-fronted Barbet.

6. *Turdoides striatus striatus*, the Ceylon Babbler.—A somewhat uncommon resident in the lower parts of the Estate. Nests usually about February and March.

9. *Pomatorhinus horsfieldii melanurus*, the Ceylon Scimitar-babbler.—A common resident in the upper jungles. Nests usually during March and April, but a nest has been found as early as February 10th and as late as May 8th. The usual clutch is three eggs.

10. *Dumetia albogularis albogularis*, the Small White-throated Babbler.—A very common resident throughout the Estate, nesting from January to August; usual clutch is three eggs.

11. *Chrysomma sinensis nasalis*, the Ceylon Yellow-eyed Babbler.— An uncommon resident among the ' mana '-grass of the patanas, on the lower parts of the Estate. Two nests, containing c/2 and c/3 respectively, have been found during May.

12. *Pellorneum fuscocapillum*, the Brown-capped Babbler.—A moderately common resident in the surrounding jungles. Nests have been found during April and December. Two eggs seem to be the usual clutch but one nest contained three. During the nesting season the call note of this species becomes monotonous.

13. *Rhopocichla atriceps nigrifrons*, the Black-fronted Babbler.— A very common resident in the cardamom jungles. Nests containing eggs have been found in February, April and May, and again in October and November. The usual clutch is two but three eggs have been found on several occasions.

14. *Aegithina tiphia multicolor*, the Ceylon Iora.—A rather uncommon resident in the jungles and gardens on the lower part of the Estate. The nest has not been found, although the bird is known to breed in the vicinity.

15. *Chloropsis aurifrons davidsoni*, the Malabar Chloropsis.—An occasional visitor—is probably resident in the lower parts of the Estate. Jerdon's *Chloropsis* (*Chloropsis jerdoni*) may also occur, occasionally.

17. *Microscelis psaroides ganeesa*, the Southern Indian Black Bulbul.—An extremely common resident in all the jungles surrounding the Estate. Breeds chiefly during April, laying two eggs but nests have been found, also, during March, May, July, and September.

18. *Molpastes cafer cafer*, the Madras Red-vented Bulbul.—An extremely common resident throughout the Estate. Nests, intermittently, throughout the year.

21. *Pycnonotus luteolus*, the White-browed Bulbul.—Occasionally seen among the bushes on the lower part of the Estate. A nest containing two eggs was found on April 26.

22. *Kelaartia penicillata*, the Yellow-eared Bulbul.—A very common resident in all the upper portions of the Group. Nests in March and April and again in August, September, and October, laying two eggs.

25. *Saxicoloides fulicata fulicata*, the Black-backed Indian Robin.—A common resident throughout the Estate, nesting during April and May and again in August, September, and October and laying either two or three eggs.

26. *Copsychus saularis ceylonensis*, the Ceylon Magpie-Robin.—A common resident, nesting during April and May. Either three or four eggs are laid, in a hole in a tree or stump.

27. *Kittacincla malabarica indica*, the Indian Shama.—Common in the jungles immediately below the Estate.

28. *Larvivora brunnea*, the Himalayan Blue Chat.—A regular migrant; resident and common throughout the north-east monsoon period. Generally arrives during October. As many as five have come into the bungalow on a misty evening when they have been on passage. Almost all those coming into the bungalow or fluttering against the window panes have been either female or immature males.

29. *Turdus Merula kinnisii*, the Ceylon Blackbird.—A rather uncommon resident in the higher jungles; more common in those years when the ' Nillu ' is seeding. Nests have been found during March and November. The usual clutch is three eggs.

30. *Geokichla wardii*, the Pied Ground Thrush.—A regular passage migrant, both during October and again during March. A few appear to stay with us throughout the north-east monsoon period. Several females, or males in immature plumage, have come into the bungalow on misty evenings. On the

spring migration as many as seven or eight males, in the full back and white plumage, have been seen together in one of the small strips of jungle.

32. *Monticola solitaria pandoo*, the Eastern Blue Rock Thrush.—A regular north-east monsoon migrant to one or two rocky parts of the Group,. Most of the birds seem to be on passage and to remain with us for a few days or a week only. All the birds seen have been either females or immature birds. As many as three were seen on one occasion.

33. *Oreocincla dauma imbricata*, the Ceylon Thrush.—A rather rare resident in the more isolated and higher jungles. Nests, containing two eggs each, have been found in March and April. One nest was a very large pyramidical collection of moss, with a deep cup in the centre, placed at the top of a sapling in dense jungle: another was a smaller collection of moss, placed upon a ledge of rock in a ravine in the forest.

34. *Oreocincla spiloptera*, the Spotted-winged Thrush.—A common resident in the upper portion of the Group. Nests during March, April, and May and again during July, August, September and October, laying, generally two eggs. The nest is composed chiefly of moss and is placed in the low fork of a bush or sapling in heavy forest. This species has an attractive song.

35. *Arrenga blighi*, the Ceylon Arrenga.—An uncommon resident, living in a ravine in heavy forest near the bungalow (3,300 feet). The nest has not yet been discovered. The characteristic whistle of this Thrush may be heard, from the bungalow garden, at dusk on fine evenings.'

36. *Siphia parva hyperythra*, the Indian Red-breasted Flycatcher.—A regular and fairly common migrant, arriving about October/November and leaving about March/April.

38. *Muscicapola tickelliae jerdoni*, Oberholser's Blue Flycatcher.—A somewhat uncommon resident, in some of the more open cardamom jungles. Nests have been found in April and May. Three eggs appears to be the full complement.

39. *Eumyias ceylonensis*, the Dusky Blue Flycatcher.—A common resident in all the jungles above about 3,000 feet. Nests are commonly found in March, April, and May.

40. *Alseonax latirostris poonensis*, the Indian Brown Flycatcher.—A common migrant, resident throughout the north-east monsoon period.

41. *Alseonax muttui muttui*, Layard's Flycatcher.—A very unusual visitor. One of these rare Flycatchers was seen in a small jungle, altitude about 1,500 feet, not far from the Group, on March 26, 1934.

42. *Culicicapa ceylonensis ceylonensis*, the Grey-headed Flycatcher.—A common resident in the higher jungles. The nest is generally well concealed amongst moss and difficult to find. A nest, found on February 28, contained three eggs.

43. *Tchitrea paradisi paradisi*, the Indian Paradise Flycatcher.—An occasional visitor to the lower part of the Estate.

44. *Hypothymis azurea ceylonensis*, the Ceylon Black-naped Flycatcher.—A somewhat uncommon resident in the more open cardamom jungles and among the tea-seed bearers. Nests, found during April, contained two and three eggs respectively.

45. *Leucocerca aureola compressirostris*, the Ceylon White-browed Fantail Flycatcher.—An occasional fairweather visitor which does not seem to be able to establish itself. This species is resident in many parts of the Matale District, including Matale town.

47. *Lanius cristatus cristatus*, the Brown Shrike.—An extremely common north-east monsoon migrant. As many as nine have come into the bungalow on a misty evening, while migration has been in progress.

49. *Hemipus picatus picatus*, the Black-backed Pied Shrike.—A fairly common resident. Has been observed. during April, building its nest on a high tree in the jungle.

50. *Tephrodornis pondiceriana affinis*, the Ceylon Wood-shrike.—A rather uncommon resident, or frequent visitor, in the lower part of the Estate. The nest has been found towards the end of May.

51. *Pericrocotus flammeus flammeus*, the Orange Minivet.—A fairly common resident throughout the Estate. The nest is, however, very difficult to discover.

52. *Pericrocotus cinnamomeus malabaricus*, the Malabar Small Minivet.—A fairly common resident, of about the same standing as the last species. A very neat little nest, discovered on April 28th, contained two eggs.

53. *Lalage sykesii*, the Black-headed Cuckoo-Shrike.—A somewhat uncommon resident. A nest found on April 27th, contained two eggs.

55. *Artamus fuscus,* 'the Ashy Swallow Shrike.—A very occasional visitor to the lower part of the Estate. Resident in the Matale District and common at times over Matale town.

58. *Dicrurus coerulescens leucopygialis,* the White-vented Drongo. —A common resident throughout the Estate. Nests during March and April, laying either two or three eggs.

60. *Dissemurus paradiseus ceylonensis,* the Ceylon Racket-tailed Drongo.—Resident in the heavy forest just below the Estate.

63. *Acrocephalus dumetorum,* Blyth's Reed Warbler.—A common north-east monsoon migrant, arriving about October and resident until the following March or April. Sometimes comes into the bungalow on misty evenings.

64. *Elaphrornis palliscri,* Ceylon Warbler.—A fairly common resident throughout the jungles, above approximately 3,300 feet. Nests later in the year than the majority of residents. Nests have been found in June, July, August, and September.

65. *Orthotomus sutorius sutorius,* the Indian Tailor-Bird.—A common resident, nesting from March to September. Is always to be found around the gardens of the labourers' lines.

66. *Cisticola juncidis omalura,* the Ceylon Streaked Fan-tail Warbler.—Occasionally seen amongst the long grass in some of the patnas. Probably resident throughout the year.

72. *Acanthopneuste nitidus nitidus,* the Green Willow Warbler.—A fairly common north-east monsoon passage migrant, passing through about October-November and again about March-April.

75. *Prinia socialis socialis,* the Ashy Wren-Warbler.—A fairly common resident in the patanas and chenas around the Estate. Nests have been found during April and May and again in July and September. There are generally three eggs but four were found on one occasion.

77. *Prinia inornata jerdoni,* the Ceylon Wren-Warbler.—A common resident in the patanas on the lower part of the Group. Nests containing either three or four eggs have been found in March, April, September and October.

80. *Oriolus xanthornus ceylonensis,* the Ceylon Black-headed Oriole.—A fairly common resident in the lower part of the Estate. Nests containing two eggs each have been found in March, and December.

82. *Gracula ptilogenys*, the Ceylon Grackle.—Resident in small numbers in some of the tall forests. Nests containing two eggs each have been found in April and in August. The usual site for the nest is in an abandoned woodpecker's hole in a decaying tree.

86. *Acridotheres tristis melanosternus*, the Common Ceylon Mynah. —A frequent visitor to the lower parts of the Estate. Nests in the villages just below.

90. *Uroloncha striata striata*, the White-backed Munia.—A very common resident. Nests throughout almost the whole year.

91. *Uroloncha kelaarti*, the Ceylon Munia.—A common resident Frequently nests in a creeper on the walls of the Estate Bungalow. Generally lays five eggs.

93. *Uroloncha punctulata punctulata*, the Spotted Munia.—A very common resident, especially in the lower part of the Estate. Nests intermittantly throughout the greater part of the year.

95. *Passer domesticus nigricollis*, the Burmese House Sparrow.— Common and resident at Gammaduwa. An occasional visitor to the Esate during the fine weather months.

96. *Hirundo rustica gutturalis*, the Eastern Swallow.—A common migrant, resident during the north-east monsoon.

97. *Hirundo javanica domicola*, the Nilgiri House Swallow.—Resident in small numbers. Nests regularly on the Estate Factory and in the neighbouring bungalows.

99. *Hirundo daurica hyperythra*, the Ceylon Swallow.—A common resident, throughout the Estate. Nests containing two eggs each have been found in April and May.

102. *Motacilla cineria caspica*, the Gray Wagtail.—A common resident during the north-east monsoon period. Arrives early in September and leaves again during April.

104. *Dendronanthus indicus*, the Forest Wagtail.—An occasional visitor during the north-east monsoon period.

107. *Anthus richardi rufulus*, the Indian Pipit.—A common resident on the patanas and grassfields. Nests chiefly in April and May, laying three eggs.

111. *Zosterops palpebrosa egrgia*, the Small Ceylon White-eye.— A very common resident in the lower parts of the Estate. Nests chiefly during April, laying two eggs.

112. *Zosterops ceyloncnsis*, the Large Ceylon White eye.—A very
common resident in the upper portion of the Estate and
the surrounding jungles. Nests chiefly from March to May,
laying generally three eggs, but nests have been found in
July and October.

114. *Leptocoma asiatica asiatica*, the Purple Sunbird.—An
occasional visitor but not at all common. May occasionally
nest in the lower part of the Estate.

116. *Leptocoma zeylonica*, the Purple-rumped Sunbird.—A very
common resident. Nests chiefly during March, April, and
May, laying two eggs.

117. *Dicaeum erythrorhynchus ceylonense*, Tickell's Flower
pecker.—A common resident, throughout the whole Estate
and especially common among the grevillias on the lower
part of the Group.

120. *Pitta brachyura*, the Indian Pitta.—A common passage
migrant. On one occasion no less than seven came into
the bungalow, attracted by the lights, on a misty evening
in September; on another occasion four came in, accompanied
by several Blue chats.

122. *Picus chlorolophus wellsi*, the Ceylon Yellow-naped Wood-
pecker.—Resident in small numbers in the jungles around
the Estate. Nests containing respectively one egg and two
eggs have been found in April and July.

124. *Yungipicus nanus gymnophthalmus*, the Ceylon Pigmy Wood-
pecker.—A frequent visitor throught the Estate. Most
probably a resident. nesting in the dead branches of the
albizzias.

127. *Brachypternus benghalensis erithronotus*, Red-backed Wood-
pecker.—Resident in small numbers in the lower part of the
Estate and surrounding jungles. A nest, found in a grevillea
tree during May, contained three eggs.

129. *Chrysocolaptes guttacristatus stricklandi*, Layard's Wood-
pecker.—A fairly numerous resident in the jungles
surrounding the higher parts of the Estate. A nest found on
March 22nd, contained three eggs.

130. *Thereiceryx zeylanicus zeylanicus*, the Ceylon Green
Barbet.—Occasionally seen in the lower part of the Estate.
Believed to be resident in the jungles immediately below.

181. *Cyanops flavifrons*, the Yellow-fronted Barbet.—A very common resident, nesting freely in the albizzias trees during March, April, and May and again during August, September, and October. Generally three eggs are laid.

133. *Xantholaema rubricapilla*, the Small Ceylon Barbet.—Resident in small numbers.

136. *Merops orientalis orientalis*, the Common Indian Bee-eater.— A very uncommon visitor. Several were seen, on one occasion, sitting on some low trees at an altitude of 3,300 feet.

137. *Merops superciliosus javanicus*, the Blue-tailed Bee-eater.— A common north-east passage migrant. Generally seen flying over.

138. *Melittophagus erythrocephalus erythrocephalus*, the Chestnut-headed Bee-eater.—An occasional fair weather visitor. Usually seen flying over or hawking insects on the lower patanas.

140. *Alcedo atthis taprobana*, the Ceylon Kingfisher.—Resident in small numbers on the streams in the lower part of the Estate.

144. *Halcyon smyrnensis generossa*, the Ceylon White-breasted Kingfisher.—A fairly common resident in the lower part of the Estate. Nests containing either four or five eggs have been found in May

147. *Tockus griseus gingalensis*, the Ceylonese Hornbill.—An annual visitor, in small troops, during the fine weather of September and October. Resident in the jungles below the Estate.

149. *Micropus melba bakeri*, the Alpine Swift.—Common in the air above the Estate, in fine weather. Nests during March in the Dumbanagala cliffs, above St. Martins Estate, some 20 miles distant (see *Ceylon J. of Sci.* (B), Vol. XVIII, p. 252).

150. *Micropus affinis nipalensis*, the Nepal House Swift.—A common resident, except in very windy weather. A colony nests annually under an overhanging rock in the lower part of the Estate.

151. *Cypsiurus batassiensis batassiensis*, the Palm Swift.—A frequent fine weather visitor. Nests below the Estate, at Gammaduwa.

152. *Hirundinapus giganteus indicus*, the Brown-necked Spinetail.— A frequent visitor during the greater part of the year. This species has been observed during every month with the exception of July and August; it possibly nests in the vicinity.

153. *Collocalia unicolor unicolor*, the Indian Edible-nest Swiftlet.—
Very common in the air above the Estate, throughout the
year. Most probably nests in the vicinity.

154. *Hemiprocne coronata*, the Indian Crested Swift.—An occasional
fine weather visitor. Nests in the trees near the Gamma-
duwa District Church.

159. *Harpactes fasciatus fasciatus*, the Malabar Trogon.—Resident
in small numbers in the tall forests around the Estate. Three
nests, containing three eggs each. have been found during
March and April.

164. *Cacomantis merulinus passerinus*, the Indian Plaintive
Cuckoo.—An occasional visitor during the north-east monsoon.

166. *Surniculus lugubris stewarti*, the Ceylon Drongo Cuckoo.—An
occasional straggler, in small bands On one or two occasions
small companies of four or five of these birds have been
resident for a few days.

173. *Centropus sinensis parroti*, the Southern Crow-Pheasant.—A
common resident—nests containing two eggs each have been
found in February and in September.

178. *Psittacula cyanocephala cyanocephala*, the Western Blossom-
headed Paroquet.—A frequent visitor. Nests in holes in
trees in the lower parts of the Estate, during March and
April.

180. *Coryllis beryllinus*, the Ceylon Loriquet.—A common resident,
nesting freely in some of the jungles adjacent to the Estate.
A nest, found on July 24th, contained three eggs.

184. *Strix indranee indranee*, the Brown Wood Owl.—Resident in
small numbers in the jungles around the Estate. This owl
sometimes gives voice to a peculiar cry, commencing with
a whistling hiss, as of escaping air, and ending in a scream.
Two of these owls so scared the Tamil labourers on the
Estate, in October last year, that they had to be shot. The
labourers called them ' Devil Birds ' and feared that they
were the forerunners of some catastrophy.

185. *Ketupa zeylonensis zeylonensis*, the Brown Fish-Owl.—A com-
mon resident in the jungles around the Estate. A nest,
containing two eggs, was found on the 11th March, 1931.

186. *Huhua nipalensis*, the Forest Eagle-Owl.—An occasional
visitor to the heavy forest areas; one, shot in a neighbouring
jungle, was brought in, some 18 months ago, by a labourer.

187. *Otus sunia leggei*, the Ceylon Scops Owl.—An occasional visitor during the fine weather, between the north-east and south west monsoon (see *Ceylon J. of Sci.* (B), Vol. XVII, p. 98).

188. *Otus bakkamoena bakkamoena*, the Collared Scops Owl.— Occasionally seen and heard in the evenings. Resident in some of the jungles in the near vicinity. A nest, discovered in an albizzia tree, on April 9th, contained three eggs.

196. *Lophotriorchis kieneris*, the Rufous-bellied Hawk-Eagle.—An occasional visitor. Some years ago, one was observed to stoop at the headcloth of a labourer as he was emerging from dense jungle.

197. *Ictinaetus malayensis perniger*, the Indian Black Eagle.—A common visitor during fair weather—very probably nests in some of the jungles adjoining the Estate. A confiding species that often comes within a few yards of the observer.

198. *Limnaetops cirrhatus ceylonensis*, the Ceylon Hawk-Eagle.— A fairly common resident Most probably nests in the jungle adjoining the Estate. Several individuals, that have contracted the habit of fowl stealing, have had to be shot.

199. *Limnactops nipalensis kelaarti*, Legge's Hawk-Eagle.—A frequent visitor that may nest in the surrounding jungles A fine specimen was shot by a labourer, on March 24th, 1931, while it was attacking his fowls.

200. *Haematornis cheela spilogaster*, the Ceylon Serpent-Eagle — A common resident. Undoubtedly nests in the jungles around the Estate. Some years ago I observed one of these eagles eating a large yellow centipede

205. *Elanus coeruleus vociferus*, the Black-winged Kite.—A rather uncommon fine weather visitor. Does not generally stay for more than a day or two.

206. *Circus macrourus*, the Pale Harrier.—A regular and common visitor to the patanas, during the north-east monsoon. Generally commonest during April, as a passage migrant

207. *Circus pygargus*, Montagu's Harrier.—An occasional but regular visitor to the patanas during the north-east monsoon.

209. *Circus aeruginosus aeruginosus*, the Marsh Harrier.—A fairly frequent visitor during the north-east monsoon.

211. *Astur badius badius*, the Ceylon Shikra.—A common resident throughout the Estate, the commonest of the hawks. Nests in the adjoining jungles.

212. *Astur trivirgatus trivirgatus*, the Crested Goshawk.—A fairly common resident. Four nests, containing two eggs each, have been found during the months of March and April.

213. *Accipiter virgatus besra*, the Besra Sparrow-Hawk.—Resident, in small numbers, in the jungles surrounding the Estate. A nest found on April 14th contained three fresh eggs and another, on April 4th, one only.

214. *Pernis ptilorhynchus ruficollis*, the Indian Crested Honey Buzzard.—An occasional but regular visitor during the north-east monsoon.

216. *Baza jerdoni ceylonensis*, Legge's Baza.—A rare visitor. One, shot on the Estate by a Museum Collector some years ago, is now in the Colombo Museum.

218. *Falco peregrinus peregrinator*, the Indian Peregrine Falcon or Shahin.—A frequent but fleeting visitor during the fine weather months.

219. *Falco severus rufipedoides*, the Indian Hobby.—On several occasions, at dusk during the north-east monsoon, a falcon, believed to be of this species, has been observed hawking for insects on, the edge of the jungle.

221. *Cerchneis tinnunculus tinnunculus*, the European Kestrel.— A very common resident during the north-east monsoon, from about the end of October to March. No Kestrels have ever been observed during the south-west monsoon.

224. *Dendrophassa bicincta leggei*, the Ceylon Orange-breasted Green Pigeon.—Green Pigeons occasionally visit the lower part of the Group and the adjacent jungles, when wild fruits are ripening.

227. *Chalcophaps indica robinsoni*, the Ceylon Bronze-winged Pigeon.—A common resident in the Estate jungles at all altitudes. Nests freely during February, March, and April and again in July and September. Two eggs only are laid.

229. *Columba torringtoni*, the Ceylon Wood-pigeon.—Resident in small numbers in the jungles on the crests of the higher ridges. Is known to nest occasionally in those jungles but no eggs have been found.

232. *Streptopelia chinensis ceylonensis*, the Ceylon Spotted Dove.— A fairly common resident in the lower portion of the Group. Nests in the grevillea trees about April and May, laying two eggs.

236. *Gallus lafayettii*, the Ceylon Jungle Fowl.—Resident in all the jungles in, and adjacent to, the Group, but only in small numbers except when the nillu is seeding when large numbers appear and stay to breed. Several nests have been found during March and April. The usual number of eggs is either three or four but one nest, found on March 22nd/31, contained nine eggs. laid probably by more than one hen.

243. *Turnix suscitator leggei*, the Ceylon Bustard Quail.—Resident in small numbers on the patnas on the lower Estate. Would be far more plentiful were the patanas not burnt off so frequently. A nest, containing three eggs, was found on July 31st, 1927.

247. *Rallina superciliaris superciliaris*, the Banded Crake.—An occasional struggler during the north-east monsoon period. One or two have been flushed out of long grass.

249. *Amaurornis phoenicurus phoenicurus*, the Ceylon White-breasted Water-hen.—A rare straggler; one or two have been flushed from long grass; they were probably passing through on a local migration.

355. *Gorsakius melanolophus melanolophus*, the Malay Bittern.— A very rare straggler. One was shot, in one of the Estate jungles, on March 23rd, 1931.

W. W. A PHILLIPS.

End of Vol. XIX.

The Indian Alpine Swift (*Micropus melba bakeri*)

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Upper Fig.   Nest and eggs of the Brown-capped Babbler (*Pellorneum fuscicapillum*)
Lower Fig   Nest and young of the crested Goshauk (*Astur trivirgatus trivirgatus*)

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Upper Fig   Nest and eggs of the Ceylon Warbler (*Elaphrornis palliseri*)
Lower Fig   Nest and eggs of the Spotted-winged Thrush (*Oreocincla spiloptera*)

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